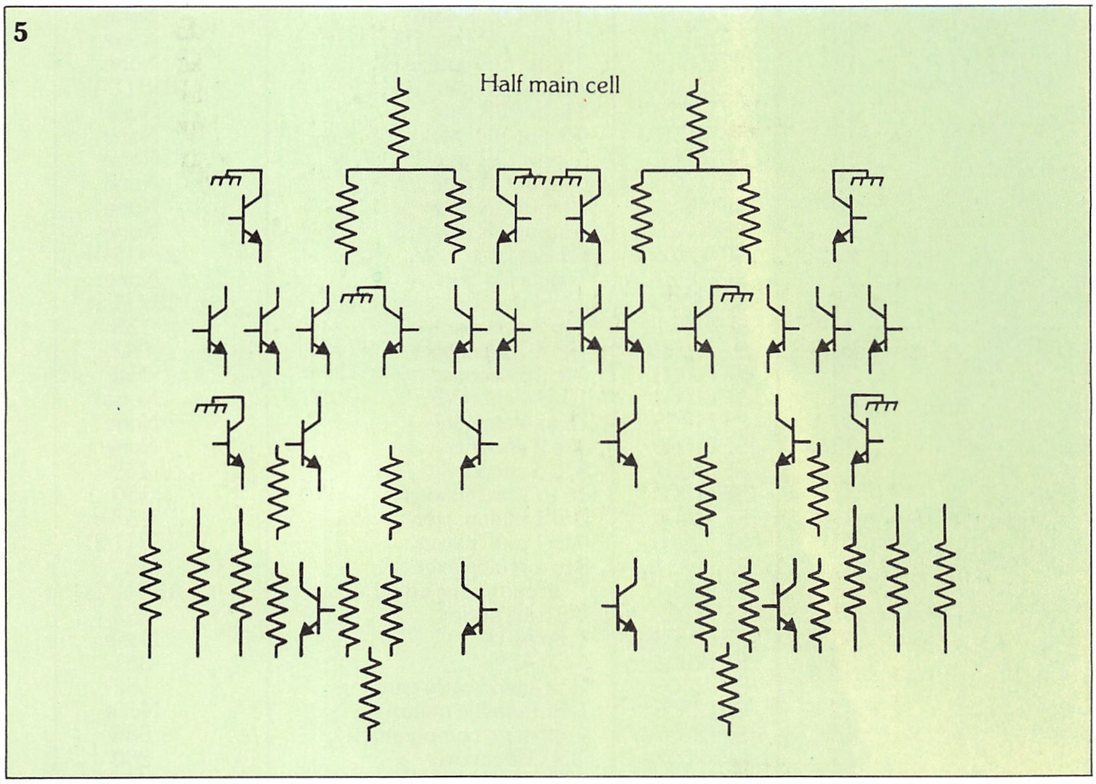
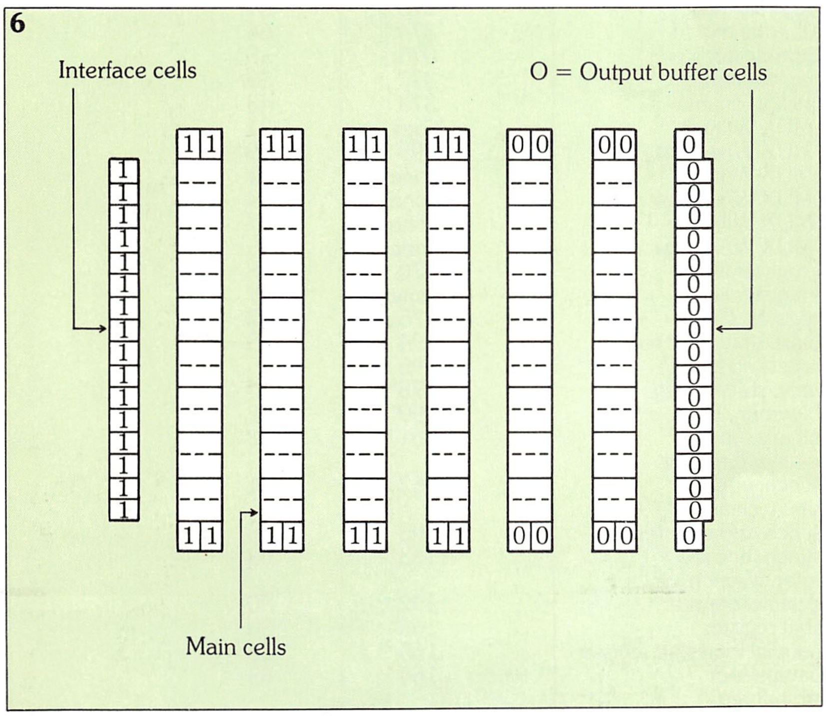
(continued from part 27)

Although the TAT 008 gate array is based on a low power Schottky construction, all other types of logic families – ECL I^2L, CMOS, TTL etc. – may be used to construct gate array integrated citcuits. Indeed, some gate array IC cells are configured merely as a collection of separate transistors and resistors, not in any logic gate configuration. *Figure 5*, for example, shows the components within one half of a main cell of a **macrocell** gate array.

5. Macrocell gate array showing components within one half of the main cell.



6. Layout of a macrocell gate array IC.



The term macrocell derives from the fact that the manufacturer holds a file of all the possible logic functions, called **macrofunctions** by the manufacturer. When a user requires a macrofunction say, an EXOR gate, in a specific cell,the file is simply accessed to locate the required connections between components to form the function. The layout of a macrocell gate array IC is shown in *figure 6* and the circuit of *figure 7* illustrates how the individual components within a cell may be connected to form the EXOR gate macrofunction. There are 48 main cells, so a total of 96 individual logic functions may be built into the IC.

Also seen on the layout of the macrocell gate array are 32 interface cells and 26 output buffer cells.

Computer aided design

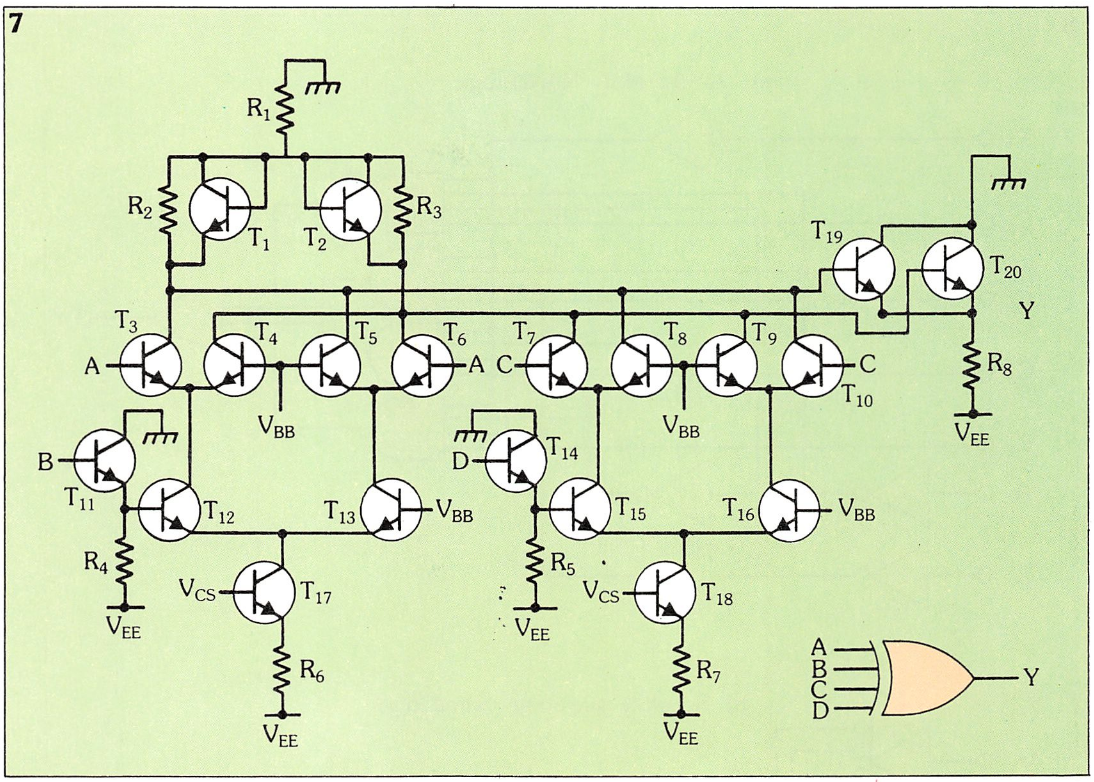
Gate arrays comprising up to only a few

Table 1

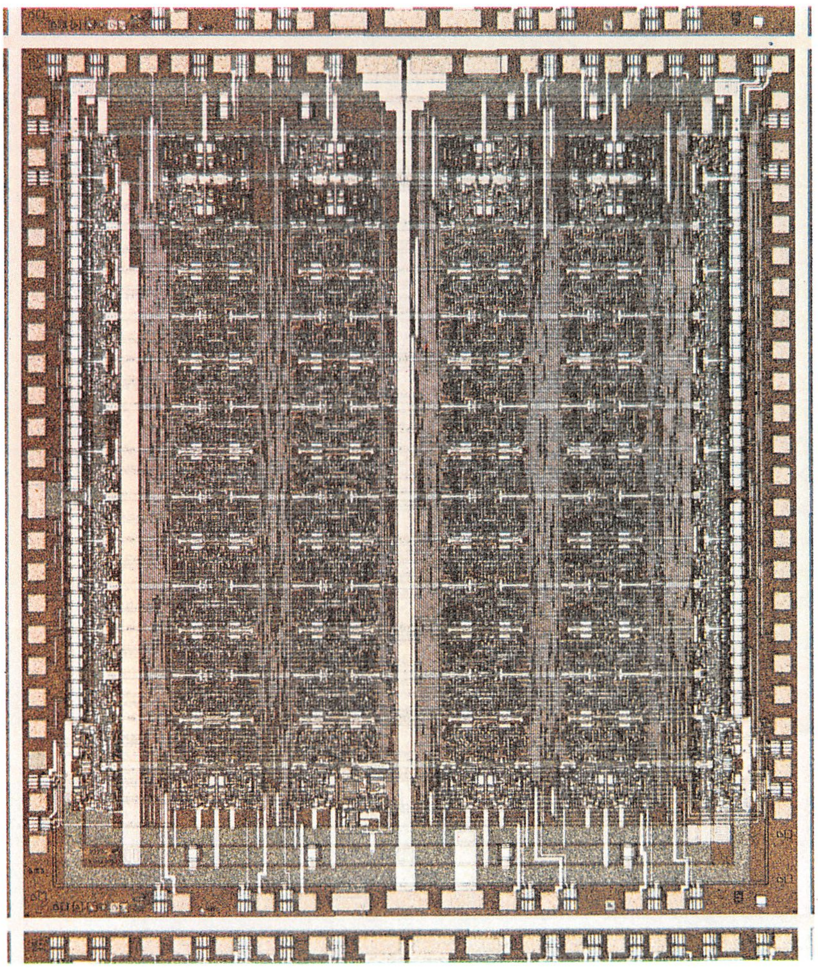
Logic functions available through HDL

Number	HDL reference	Logic function	Equivalent 74 TTL IC	Number of gates
1	SFT0004	D flip-flop	074 (1/2)	9
2	SFT0005	2 Input exclusive OR	386 (1/4)	6
3	SFT0006	3 Input exclusive OR	None	10
4	SFT0007	JK Bar flip-flop	109 (1/2)	10
5	SFT0008	Gated JK flip-flop	101	12
6	SFT0010	2 Input NOR gate	002 (1/4)	10
7	SFT0011	3 Input NOR gate	027 (1/3)	3
8	SFT0012	4 Input NOR gate	None	4
9	SFT0013	5 Input NOR gate	None	5
10	SFT0014	6 Input NOR gate	None	6
11	SFT0015	7 Input NOR gate	None	7
12	SFT0016	8 Input NOR gate	None	8
13	SFT0017	2 Input OR-gate D FF	None	9
14	SFT0018	3 Input OR-gate D FF	None	13
15	SFT0019	2 Input OR gate	032 (1/4)	3
16	SFT0020	3 Input OR gate	None	4
17	SFT0021	4 Input OR gate	None	5
18	SFT0022	5 Input OR gate	None	6
19	SFT0023	6 Input OR gate	None	7
20	SFT0024	7 Input OR gate	None	8
21	SFT0025	8 Input OR gate	None	9
22	SFT0026	SR Bar latch	279 (1/4)	2
23	SFT0027	Toggle flip-flop	None	9
24	SFT1000	2 to 4 decoder	139 (1/2)	9
25	SFT1001	3 to 8 decoder	138	25
26	SFT1002	4 to 10 decoder	042	28
27	SFT1003	4 to 16 decoder	154	46
28	SFT1004	10 to 4 encoder	None	26
29	SFT1005	16 to 4 encoder	None	57
30	SFT1006	4 to 2 encoder	None	10
31	SFT1007	8 to 3 encoder	148	24
32	SFT1008	16 to 1 multiplexer	150	45
33	SFT1009	2 to 1 multiplexer	158	13
34	SFT1010	4 to 1 multiplexer	153 (1/2)	10
35	SFT1011	8 to 1 multiplexer	151	26
36	SFT2001	1-Bit carry save adder	183 (1/2)	10
37	SFT2002	4-Bit full adder	283	56
38	SFT2003	1-Bit ALU	None	30
39	SFT2004	4-Bit ALU	381	102
40	SFT2005	look ahead carry gen.	182	31
41	SFT2006	1-Bit iterative multi.	None	16
42	SFT2007	4-Bit mag. comparator	085	35
43	SFT2008	9IN O/E checker	280	47
44	SFT2010	4-Bit multi-bit shifter	AM25S10	35
45	SFT4000	OCTAL D flip-flop	273	64
46	SFT4001	OCTAL edge trig. f/f	374	64
47	SFT4002	4-Bit bistable latch	075	5
48	SFT4003	8-Bit reg. w/enable	377	58
49	SFT4004	8-Bit latch w/enable	373	48
50	SFT4005	2 to 1 MUX W/latch	None	31
51	SFT4006	2 to 1 MUX W/storage	399	39
52	SFT4007	3 to 1 MUX W/latch	None	41
53	SFT4008	3 to 1 MUX W/storage	None	49
54	SFT4009	4 to 1 MUX W/latch	None	47
55	SFT4010	4 to 1 MUX W/storage	None	55
56	SFT4011	4 by 4 register file	170	108
57	SFT4012	4 by 8 register file	None	197
58	SFT4013	4-Bit register, dir. clr.	175	32
59	SFT6000	4-Bit bidrt. univ. shift reg.	194	59
60	SFT6001	4-Bit access shift reg.	195	45
61	SFT6002	8-Bit univ. shift str. reg.	198	113
62	SFT6003	4-Bit biquinary counter	390	32
63	SFT6004	4-Bit binary synch. counter w/direct clr.	161	62
64	SFT6005	4-Bit synch. counter w/synch. clear	162	61
65	SFT6007	4-Bit synch. u/d counter	193	65
66	SFT6008	4-Bit synch. decade counter w/synch. clr.	163	68
67	SFT6009	4-Bit decimal counter	192	80
68	SFT6011	8-Bit shift register	166	80
69	SFT6012	8-Bit parallel load shift register	165	76
70	SFT6013	8-Bit parallel-out serial shift reg.	164	65

7. Circuit showing connections within a cell forming the EXOR gate macrofunction.



Below: macrocell arrays. (Photo: Motorola Ltd).



hundred gates or components may be designed manually, using hand drawing techniques to lay out the user's circuit on the IC. However, for arrays comprising more than a few hundred components many different computer aided design (CAD) systems have been produced.

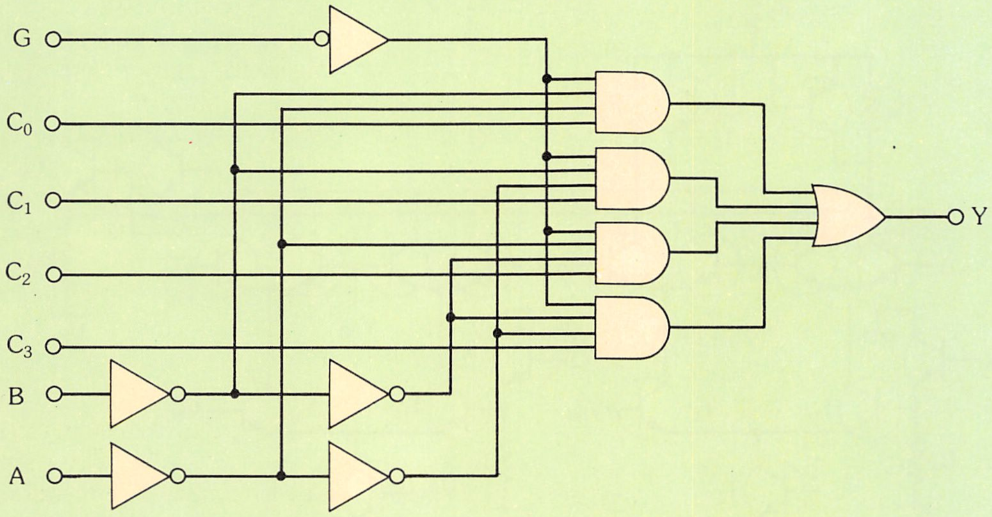
Such computer systems may be available to the user as a development tool, in which case the engineer is able to personally produce a software description of the circuit design, in such a way that it may be checked and corrected before the IC is actually produced. The data created by the engineer is then used as a basis for array layout. This, in turn, is used to generate the masks, and finally the IC itself. Alternatively, the manufacturer designs and produces all stages from the user's specification of the task the IC is to perform.

One typical CAD system, known as the **gate array design system** (GADS), uses a high level computer language – **hardware description language** (HDL) – to physically represent the user's required circuit as software.

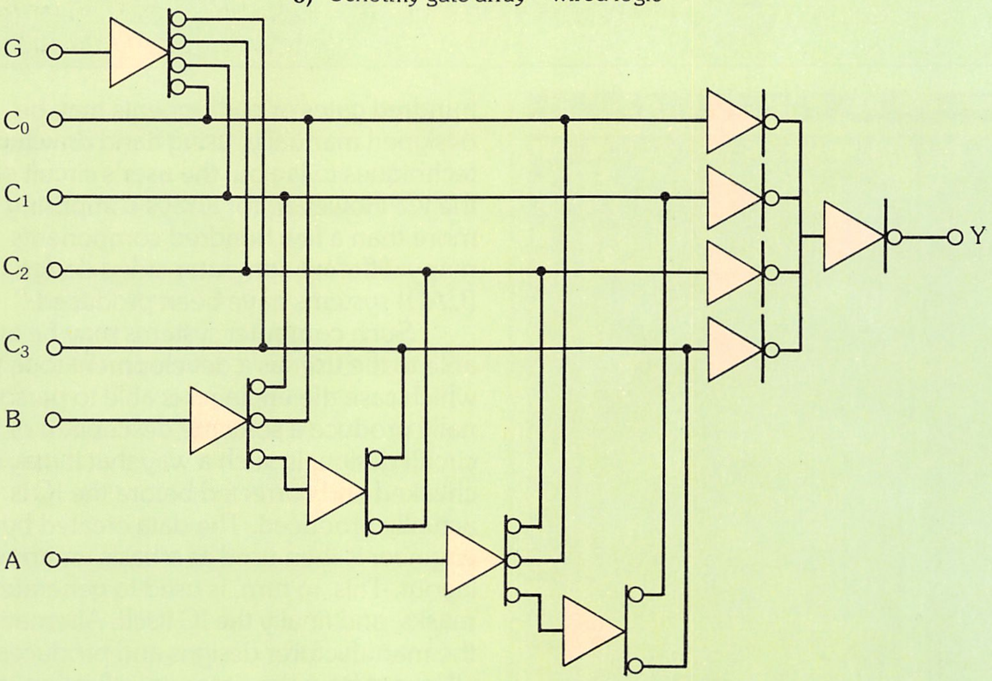
Table 1 lists the various logic functions available through HDL to describe a circuit. Using HDL on the GADS computer aided design system, any of the logic

8

a) 74S/LS MSI – NAND logic



b) Schottky gate array – wired logic



Type	74S	74LS	Gate array
Number of gates	10	10	10
Power dissipation (mW)	112	15	6
Propagation delay (ns)			
C – Y	6	13.5	5
G – Y	9	18.5	75
A, B – Y	12	22	10

8. (a) 4-line-1-line data selector; **(b)** Schottky gate array.

functions listed may be included in the software program which simulates the required hardware circuit. This software program then forms the database used to determine the array layout, and all connections within the IC. Many other CAD systems exist to perform similar jobs with other gate arrays.

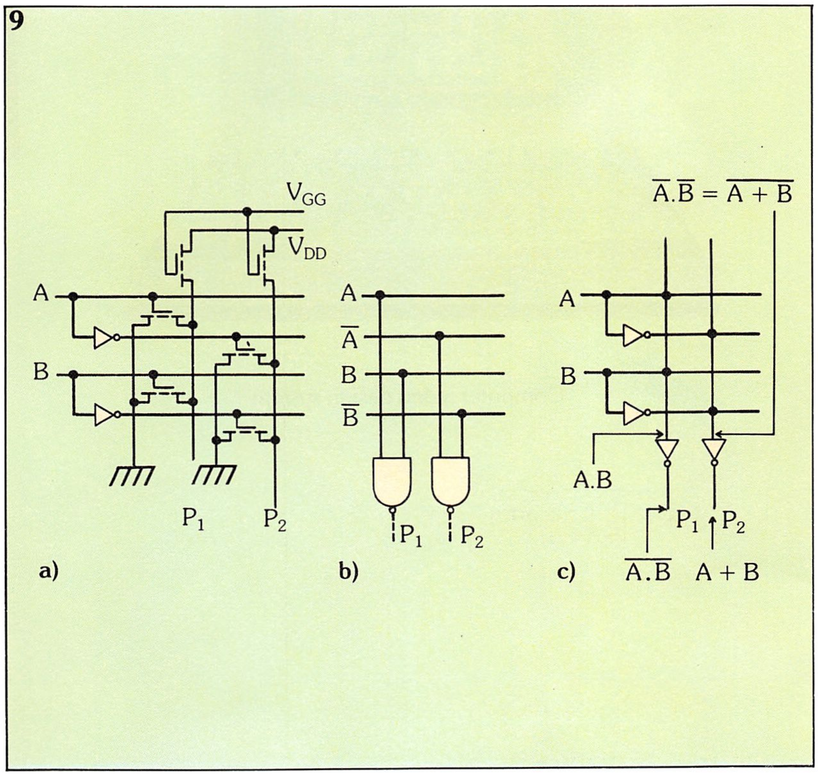
A simple example

Having looked at gate arrays and programming systems we may now consider an example of their use. *Figure 8a* shows a 4-line-to-1-line data selector constructed from a number of gates and inverters. The implementation in the Schottky-type gate array we have seen, is shown in *figure 8b*.

As we can see from the comparison table in *figure 8*, the gate array circuit dissipates far less power and also suffers much lower propagation delays.

Obviously, such a simple circuit cannot justify the high development costs associated with gate array implementation, but it does serve as a useful example. Gate arrays would usually be used for specific user applications where a large number of gates, say, over a few hundred, are used, or where the circuitry needs to be specially miniaturised, for use in portable equipment.

9. (a) Matrix PROM array; (b) its equivalent logic diagram; **(c)** simplified wired matrix form.



Programmable logic arrays

As we have seen, programmable logic arrays may be thought of as being field programmable by the user and we may also think of them in an analogous way to PROMs. We may, in fact, look closer at PROM implementation to see how programmable logic arrays operate. Consider the matrix PROM array whose electrical diagram is shown in *figure 9a*. Outputs P_1 and P_2 from the matrix are defined as functions of the inputs A and B, as:

$$P_1 = \overline{A.B}$$
$$P_2 = \overline{\bar{A}.\bar{B}}$$

The equivalent logic diagram giving these outputs is shown in *figure 9b*. This may be simplified to a wired matrix form as shown in *figure 9c*, where we can see that the matrix actually forms wired-AND connections between inputs A and B, and between inverted inputs $\bar{A}$ and $\bar{B}$. From this we can see that the outputs are actually:

$$P_1 = \overline{A.B}$$
$$P_2 = A+B$$

In other words, the matrix has provided us with an AND logic function (i.e. a NAND without the final inverter) and an OR logic function.

We may consider more complex logic functions if we take two matrices, and connect the outputs of one (matrix 1 of *figure 10a*) to the inputs of another (matrix 2). Outputs P_1 and P_2 form the outputs of matrix 1 and the inputs of matrix 2. Outputs Q_1 and Q_2 are the final outputs. *Figure 10b* shows the electrical diagram of the circuit.

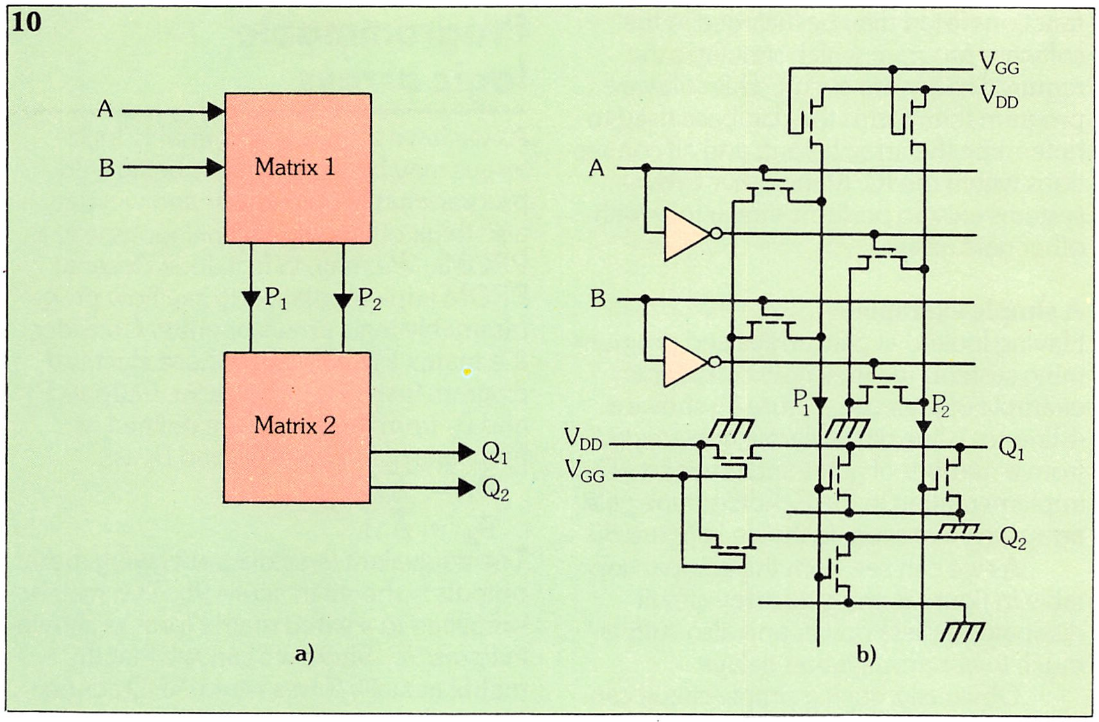
Outputs Q_1 and Q_2 may be defined as:

$$Q_1 = \overline{P_1.P_2}$$
$$= A.B + \overline{A.B}$$

and:

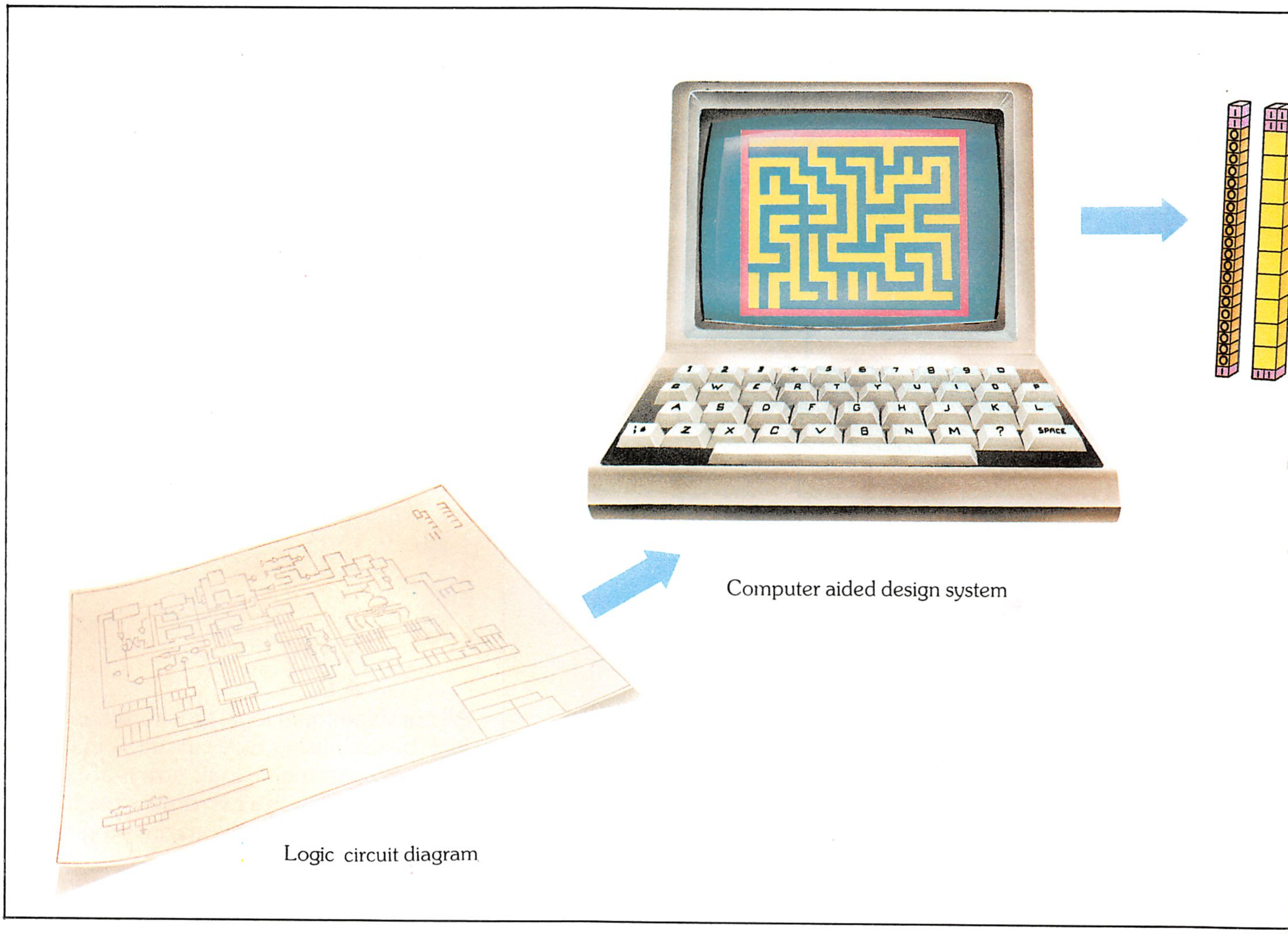
$$Q_2 = \overline{P_1}$$
$$= \overline{\bar{A} + \bar{B}}$$
$$= A.B$$

All combinational logic functions may, in fact, be built using ROM matrices in this way. Programmable logic arrays are generally produced in this two matrix manner, and specific logic functions are programmed into the integrated circuit by 'blowing' fusible links, in the same way that PROMs are programmed.

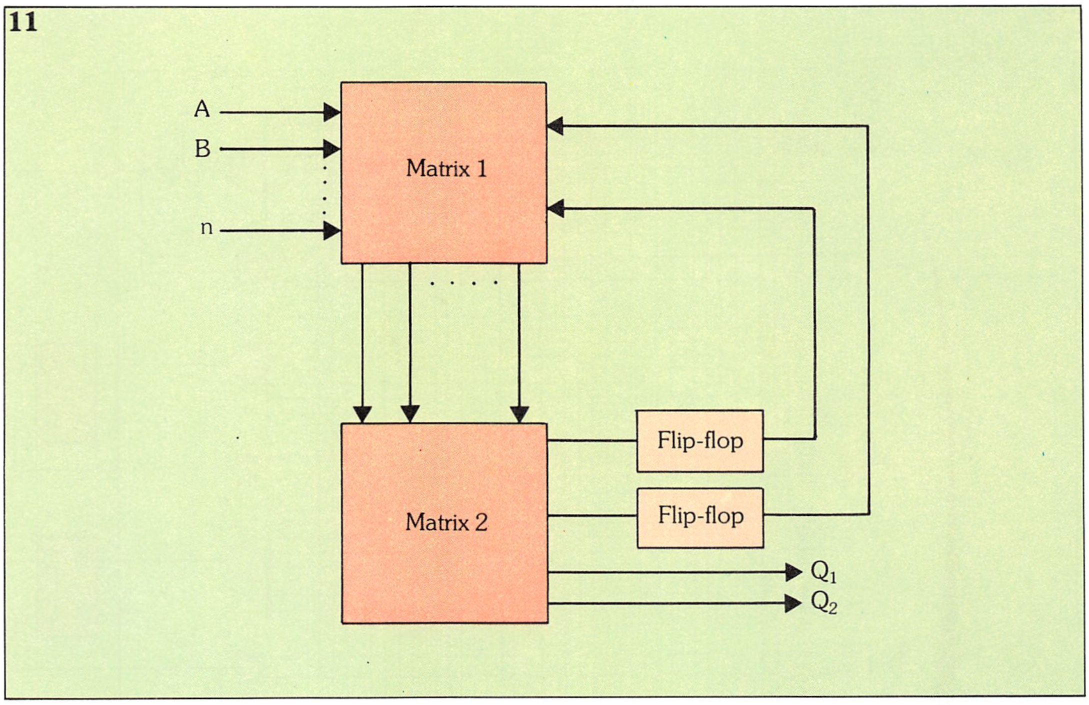


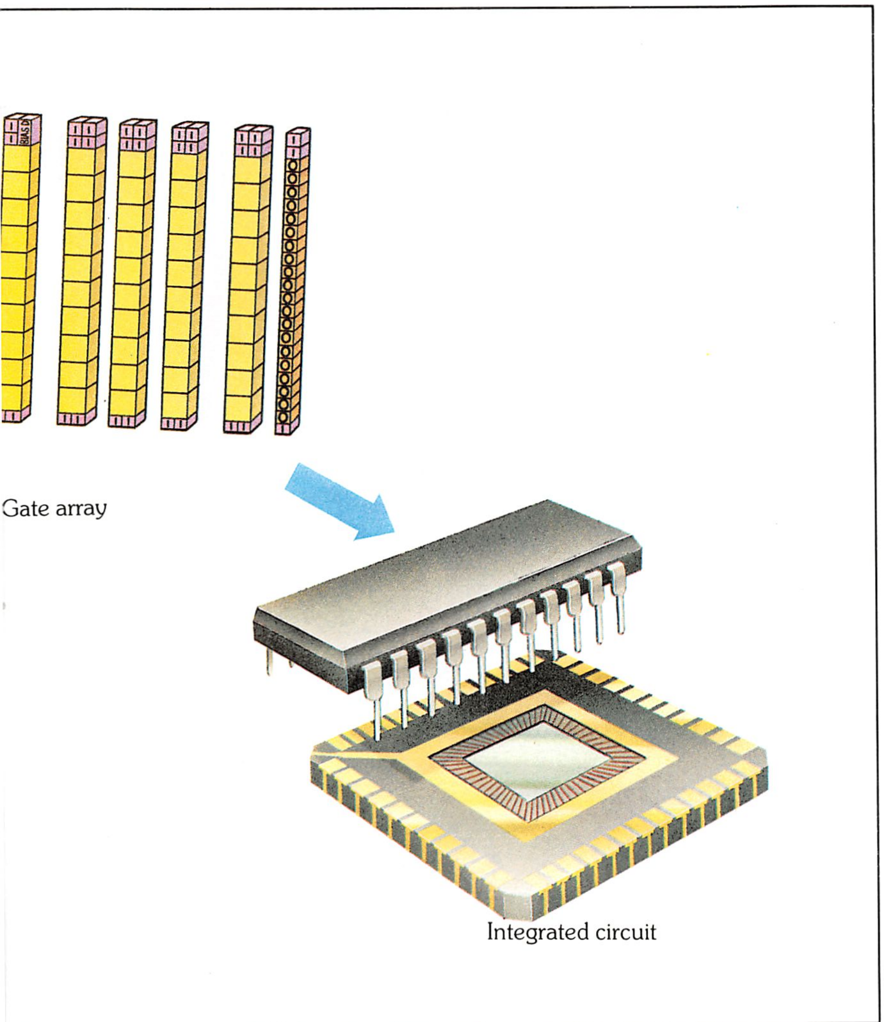
10. (a) A more complex logic function comprising two matrices; **(b)** this circuit's electrical diagram.

Below: stages in the design and manufacture of a gate array.



11. Building a two matrix PLA using flip-flops.





Sequential circuits

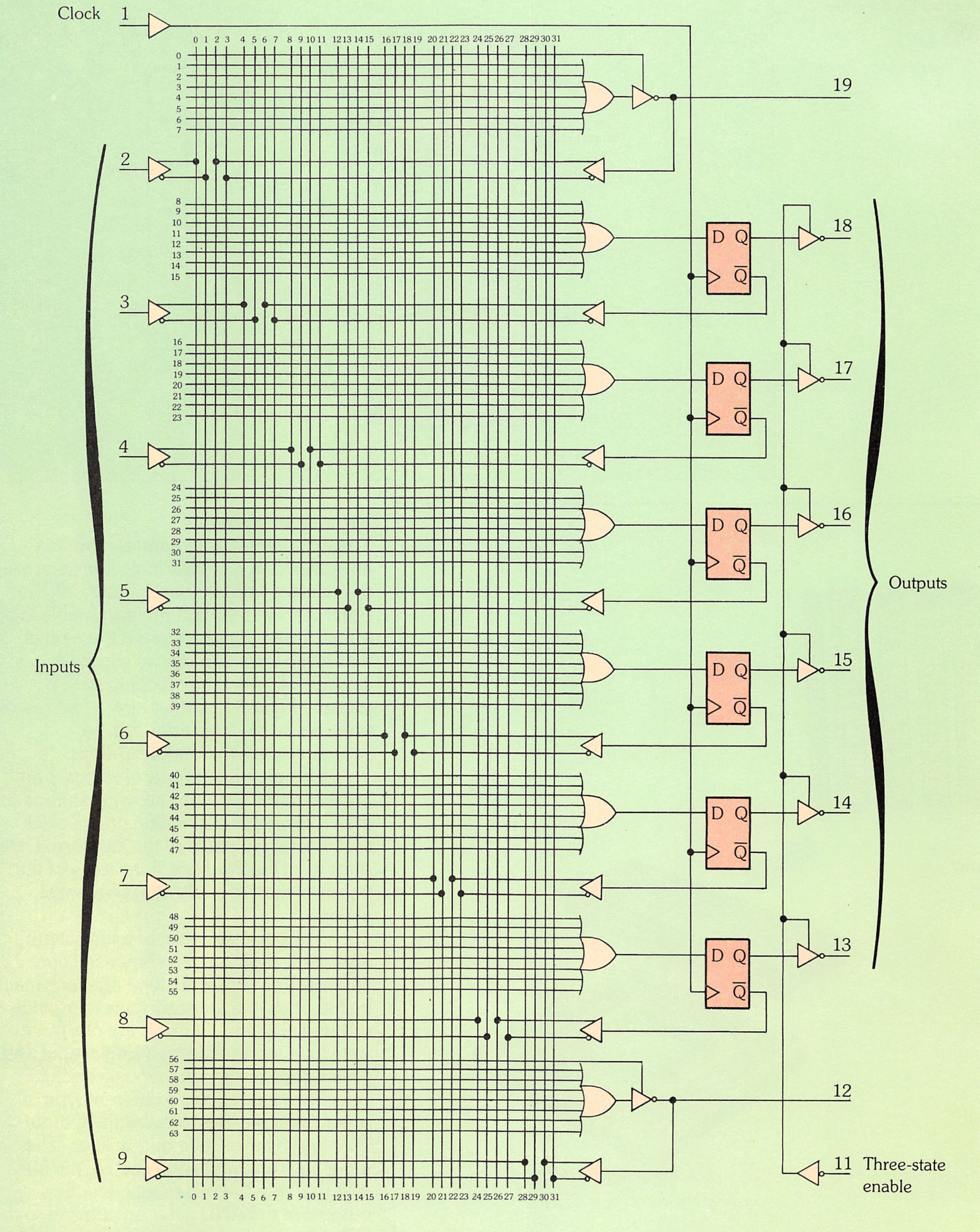
The two preceding examples of matrix arrays used to generate logic functions are, of course, combinational circuits only. In order that we may use programmable logic arrays in sequential circuits it is essential that some form of memory which is capable of storing a preceding state is present. *Figure 11* shows how a two matrix programmable logic array can be structured with the use of flip-flops.

Some of the outputs of matrix 2 are applied to the flip-flops allowing storage of their logic states depending on the clock and reset input states of the flip-flops. Data outputs of the flip-flops form some of the inputs of matrix 1, allowing sequential action.

The internal layout of a typical programmable logic array is shown in *figure 12*. Outputs from the six D-type flip-flops may be fed back to the array inputs to provide a sequential action. Outputs are of a three-state type, controlled by a single input and all flip-flops are simultaneously clocked.

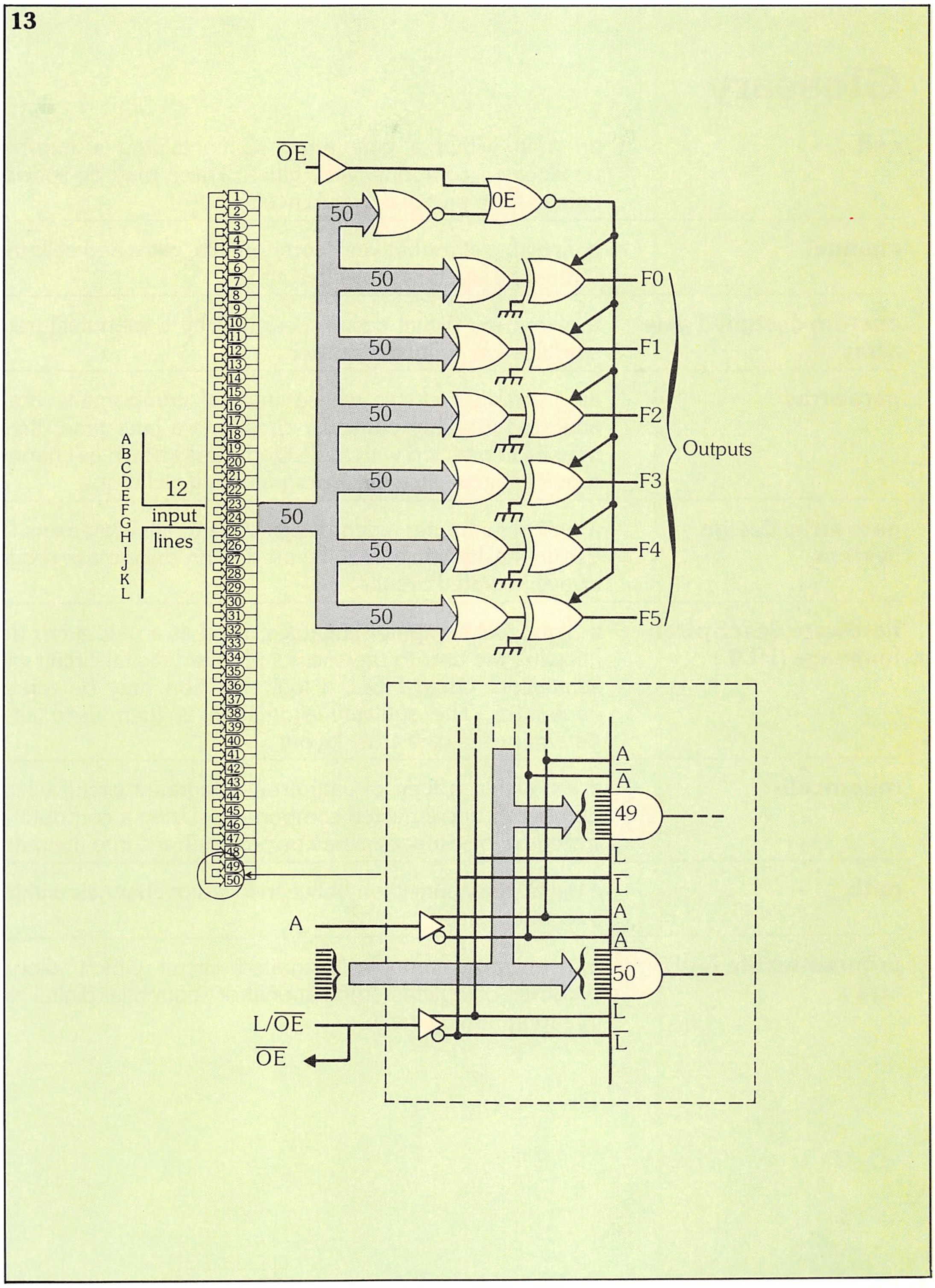
Figure 13 shows a different type of programmable logic array with 12 input lines and 6 three-state output lines. The input lines are applied to each of the 50 AND gates in the first matrix, and the outputs of the AND gates are applied to the OR gates forming the second matrix.

12


Clock
1
2
3
4
5
6
7
8
9
Inputs
19
18
17
16
15
14
13
12
11 Three-state enable
Outputs
D Q

12. Internal layout of a typical PLA.

13. A different type of PLA with 12 input lines and 6 three-state output lines.



Obviously, the fact that any logic functions – combinational and sequential – may be formed using programmable logic arrays, coupled with the fairly low development costs involved (at least where simple to medium complexity circuits are concerned) means that the devices form a very useful method of producing user designed integrated circuits.

The choice between the use of programmable logic arrays or gate arrays in any specific application will inevitably depend on the relative costs of each method with respect to the application.

Glossary

cell	an area within a gate array IC containing a number of initially unallocated components or gates. These may be specified at a later date to form part of a digital circuit
channel	connecting strips between components, gates and cells in a gate array, formed by layers of metallized strips
custom designed gate array	a gate array digital circuit, designed by a manufacturer to meet the specification defined by a user
gate array	an integrated circuit whose internal components are not initially allocated into any particular circuit. At a later time, the components may be connected with metallized strips known as channels, to form a required circuit, in a mask programming technique
gate array design system	a typical computer aided design system, allowing users to specify and design masks, which may be used to produce mask programmed gate array integrated circuits
hardware description language (HDL)	a high level computer language, used as a gate array design system, allowing the user to represent a required digital circuit with a software simulation. Using HDL, a logic function may be represented by a command. The software simulation is then used as the data to determine the gate array layout
macrocell	a cell within a type of gate array integrated circuit which contains a number of unconnected components. Using a computer aided design system, a logic function may be programmed into the macrocell
path	a metallized connection between levels of channels within a gate array integrated circuit
programmable logic array	a field programmable integrated circuit which allows a user to construct complete combinational or sequential digital circuits, simply by programming the IC

Power factor correction

An alternating voltage generator at a fixed voltage, V, delivers power, P, at a power factor, cos ϕ, to a consumer along a length of overhead transmission line. The current, I, flowing will be given by:

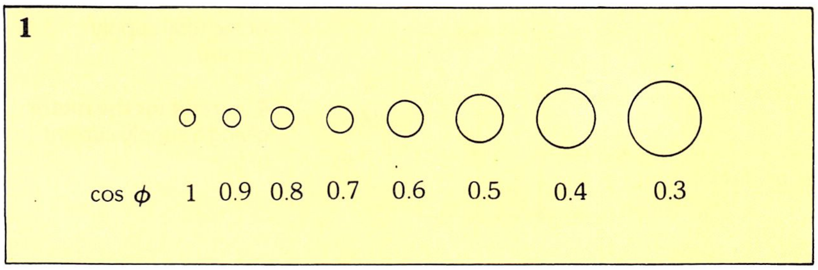
$$P = VI\cos\phi$$

so:

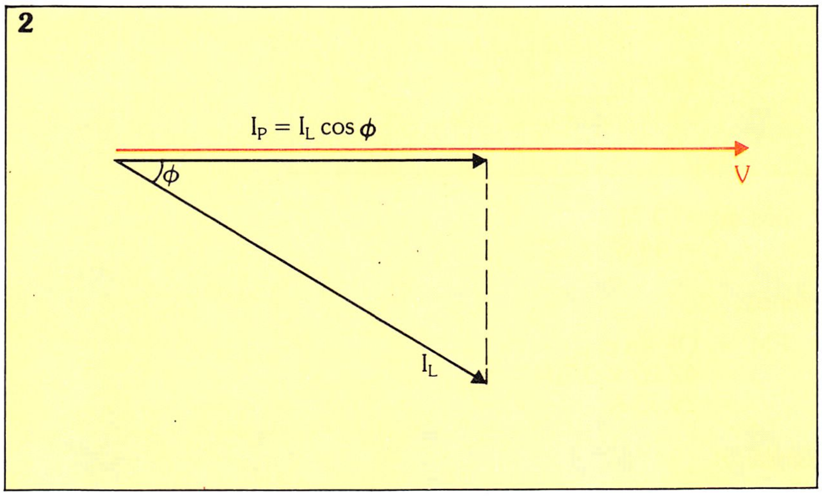
$$I = \frac{P}{V\cos\phi}$$

The power factor can vary between 0 and 1, so we can see that if P and I are fixed, the current is inversely proportional to the power factor. The current will therefore be at a minimum when cos ϕ = 1. We'll call this minimum current where:

$$I_{min} = \frac{P}{V}$$



1. Relative size of conductors which should be used with different power factors.



2. Phasor diagram for a motor supplied at a constant voltage V, taking a load current I_L, at a power factor cos ϕ.

This current is flowing along the transmission lines which of course have some resistance, R_t, so some power will be lost. The lost power, P_t, is given by:

$$P_t = I^2 R_t$$

So, if we decide that we can accept the loss of a small fraction of the transmitted power, say, 0.1%, we can see that as the current increases with increasing power factor, we have to reduce the resistance of the transmission lines. As we know, for a conductor of a fixed length, resistance is inversely proportional to its cross-sectional area.

We must also take into account the fact that the current flowing through the resistance of the transmission lines will cause a voltage drop, V_t, between the generator and the consumer, given by:

$$V_t = IR_t$$

Thus the voltage at the consumer's end of the line will be slightly lower than that at the generator, and this loss can *only* be reduced at low power factors by increasing the size of the conductors. *Figure 1* shows the relative size of conductors which should be used with different power factors.

As you can imagine, it is economically sound for the electricity generating board to persuade consumers to keep power factors as near to unity as possible because not only will the transmission lines from generator to consumer need to be enlarged, but also the size of the coils in the generator and the windings in transformers must be increased if power is delivered at low power factors.

Causes of poor power factor

The induction motor is one of the most widely used electrical motors in industry and one of the principle devices that takes current at a low power factor. The current drawn may lag the supply voltage by a power factor which may be as low as 0.5. Fluorescent lamps also show a lagging power factor, but are usually corrected for power factor by a capacitor fitted inside their filtering networks.

Power factor correction

Figure 2 shows the phasor diagram for a motor supplied at a constant voltage, V, taking a load current, I_L, at a power factor cos ϕ. The power taken is:

$$P = VI_p$$
$$= VI_L \cos\phi$$

So long as the in-phase component of current can be kept equal to the phasor, I_p, the real power consumed will be unchanged. Thus if we can add some current, I_C, to the load current, I_L, without changing its in-phase component, we shall not affect the power consumed, but we may be able to reduce the power factor of the total supply current. This is shown by the phasor diagram in *figure 3*. Here, I_S (less than I_L) is the current taken from the supply at a power factor cos θ, which is larger than the power factor of the load, cos ϕ. The power taken from the supply is unchanged

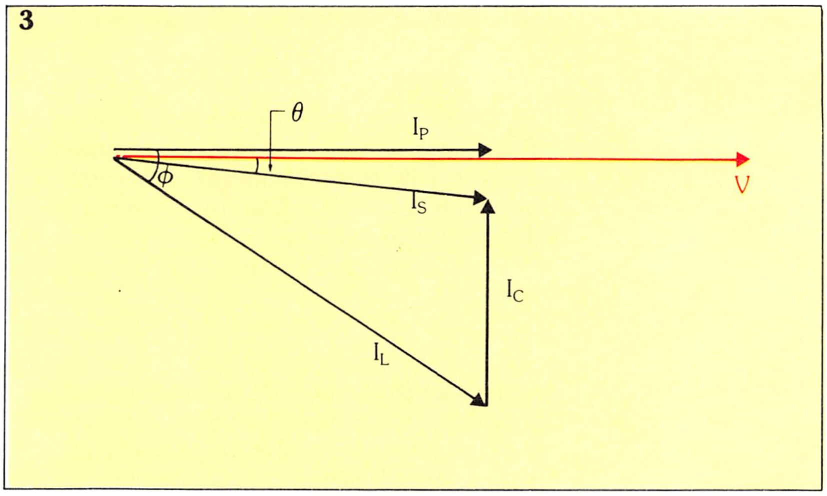
at VI_p.

Figure 3 shows that we need to connect a second circuit, in parallel with the load, which takes a current, I_C, in quadrature with the voltage and leading it. This circuit's performance can be easily identified as that of a capacitor. The complete circuit for the motor taking a current I_L, and the power factor correction capacitor taking I_C – giving a supply current of I_S – is shown in *figure 4*.

Calculation of power factor correction

An electric motor takes 120 kW at a power factor of 0.71, from a supply of 4000 V at a frequency of 50 Hz. We'll determine the value of the capacitor needed to improve the power factor to 0.9.

3



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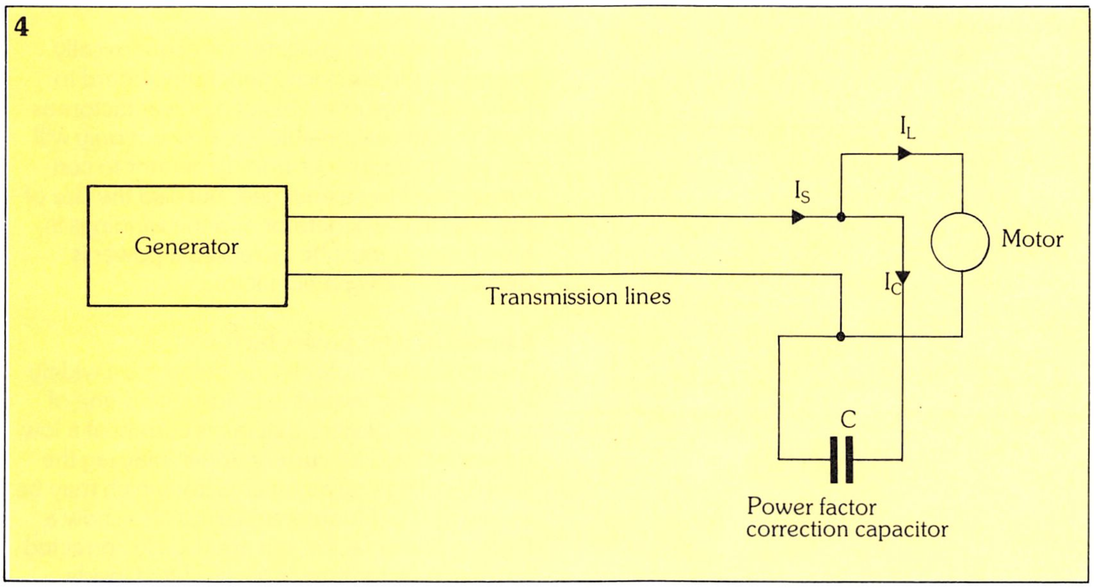


3. Adding current, I_C, to the load current, I_L, without changing its in-phase component, reduces the power factor of the total supply current.

4. Circuit for the motor giving a supply current of I_S.

The current flowing in the load is given by:

$$I_L = \frac{P}{V\cos\phi} = \frac{120 \times 10^3}{4000 \times 0.71} = 42.25\ \text{A}$$

The in-phase current is given by:

$$I_p = \frac{P}{V} = \frac{120 \times 10^3}{4000} = 30\ \text{A}$$

These currents are shown on the phasor diagram in *figure 5*. We now need to find the length of the phasor PQ, equal to I_C, so that the supply current, I_S, makes a phase angle θ, with the voltage, when:

$$\cos\theta = 0.9$$

since:

$$\cos\phi = 0.71$$
$$= 44.8°$$

Hence:

$$PM = OP\sin\phi = 42.25 \times 0.704 = 29.75\ \text{A}$$

Similarly:

$$\cos\theta = 0.9$$
$$= 25.8°$$

and again since:

$$\frac{QM}{OM} = \tan\theta$$

$$QM = OM\tan\theta = 30 \times 0.484 = 14.53\ \text{A}$$

Hence:

$$I_C = PQ$$

$= PM - QM$
$= 29.75 - 14.53$
$= 15.22\ A$

Now:

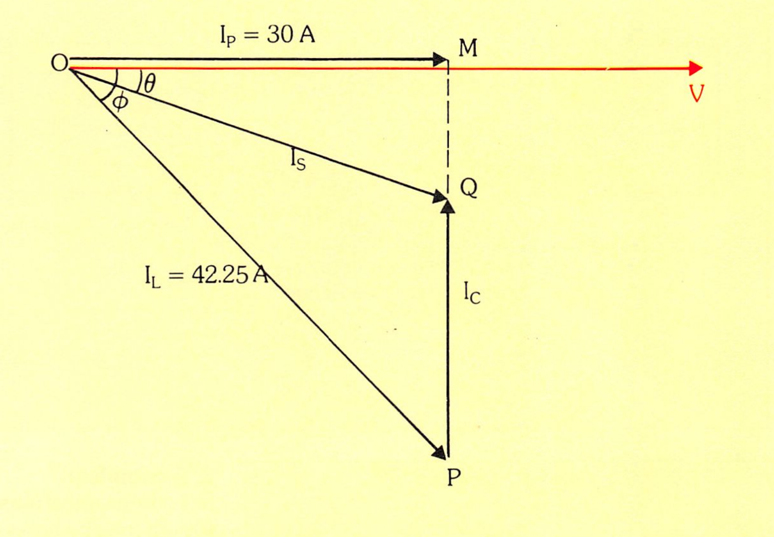
$$V = \frac{I_C}{2\pi fC}$$

hence:

$$C = \frac{I_C}{2\pi fV}$$
$$= \frac{15.22}{2 \times \pi \times 50 \times 4000}$$
$$= 1.21 \times 10^{-5}\ F$$
$$= 12.1\ \mu F$$

5. Calculating the power factor correction.

5



This calculation may be carried out in an alternative way using real, reactive and apparent power.

The real power of the system is unaffected by adding any reactive element such as a capacitor. The real power of the motor is:

$$P_L = 120\ kW$$

As the power factor is 0.71 the apparent power of the load, S_L, is given by:

$$S_L = \frac{120}{0.71}$$
$$= 169\ kVA$$

The reactive power of the motor, Q_L, is given by:

$$Q_L = S_L \sin \phi$$
$$= 169 \times 0.704$$
$$= 119\ kVAR$$

Now the real power taken from the supply P_S is:

$$P_S = 120\ kW$$

As the power factor $\cos \theta = 0.9$, we find the apparent power S_S, provided by the supply is:

$$S_S = \frac{120}{0.9}$$
$$= 133.3\ kVA$$

and the reactive power, Q_S, from the supply is:

$$Q_S = 133.3 \sin \theta$$
$$= 133.3 \times 0.436$$
$$= 58.1\ kVAR$$

The reactive power to be provided by the power factor correction capacitor is thus:

$$Q_C = Q_L - Q_S$$
$$= 119 - 58.1$$
$$= 60.9\ kVAR$$

The reactance of the capacitor is finally found from:

$$Q_C = \frac{V^2}{X_C}$$
$$X_C = \frac{V^2}{Q_C}$$
$$= \frac{4000^2}{60.9 \times 10^3}$$
$$= 262.7$$

As:

$$X_C = \frac{1}{2\pi fC}$$

the capacitance is therefore:

$$C = \frac{1}{2\pi fX_C}$$
$$= \frac{1}{2 \times \pi \times 50 \times 262.7}$$
$$= 12.1\ \mu F$$

□

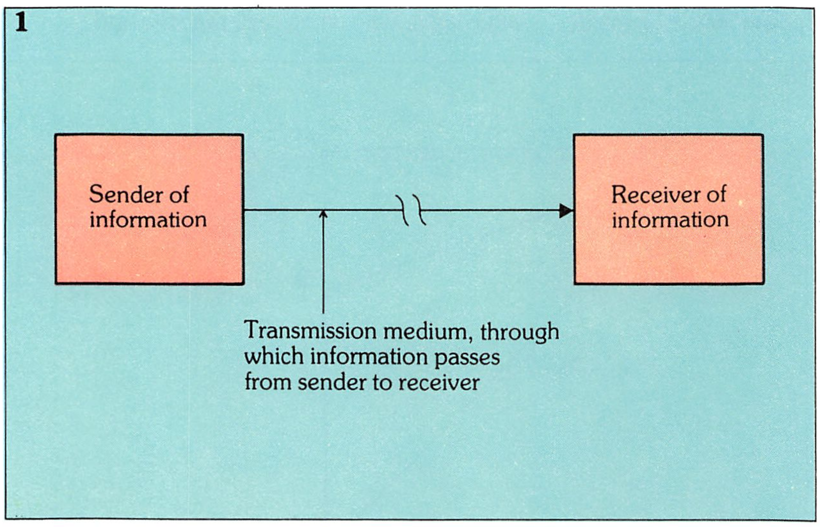
COMMUNICATIONS

The telephone-1

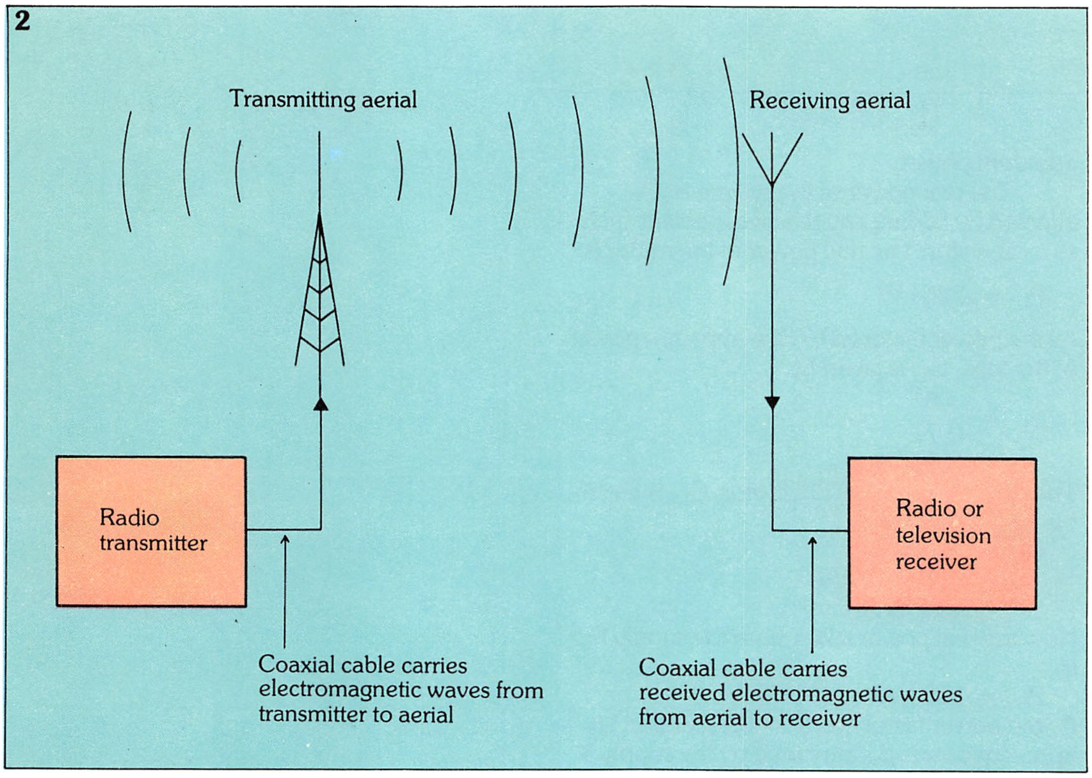
Principle of telecommunications

In the introductory chapter we saw that telecommunications is the means whereby we may communicate at a distance, using electronic methods. All communications (voice, data or telecommunications) rely on the fact that there is a *sender* of information, a *receiver* of information, and some *medium* through which the information may be transmitted. *Figure 1* illustrates this principle in block diagram form.

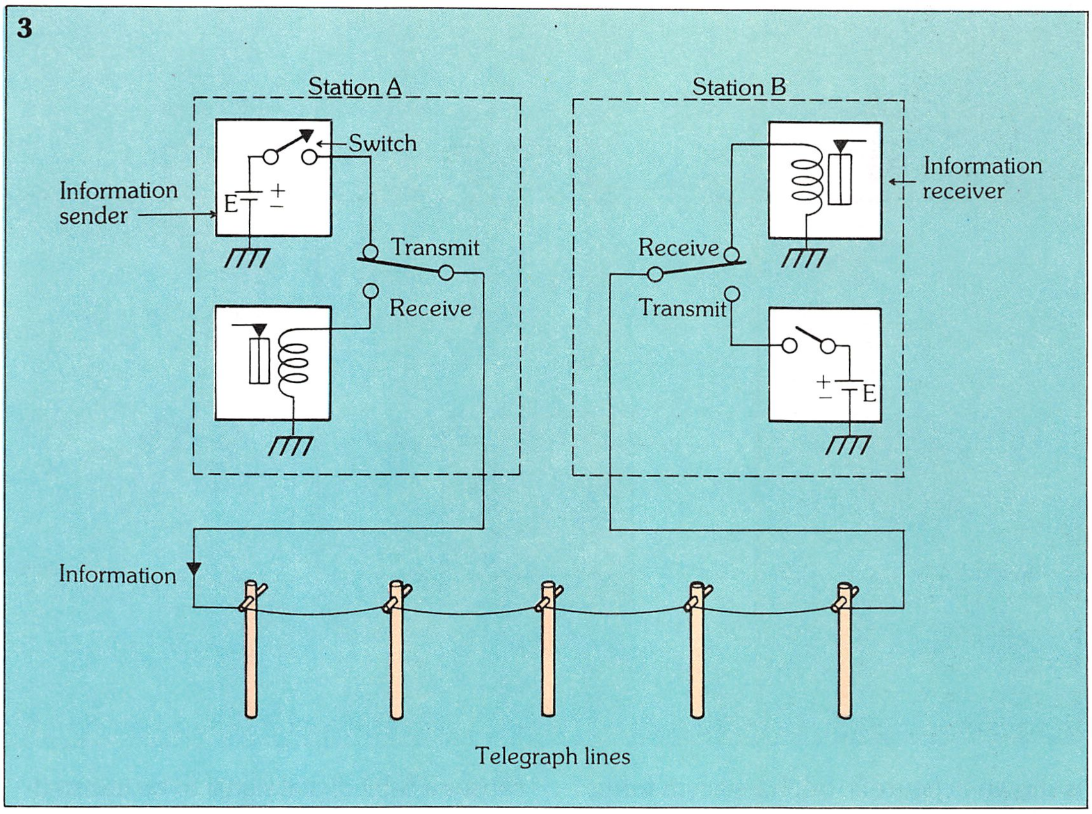
The information sender may be, as we saw, an aerial which radiates electromagnetic waves. In this case the information receiver would be a receiving aerial which is connected to, say, a radio or a television receiver, and the transmission medium is air, through which the electromagnetic waves propagate. Such a telecommunications system is shown in *figure 2*. We can also see in this example that a complete telecommunications system may



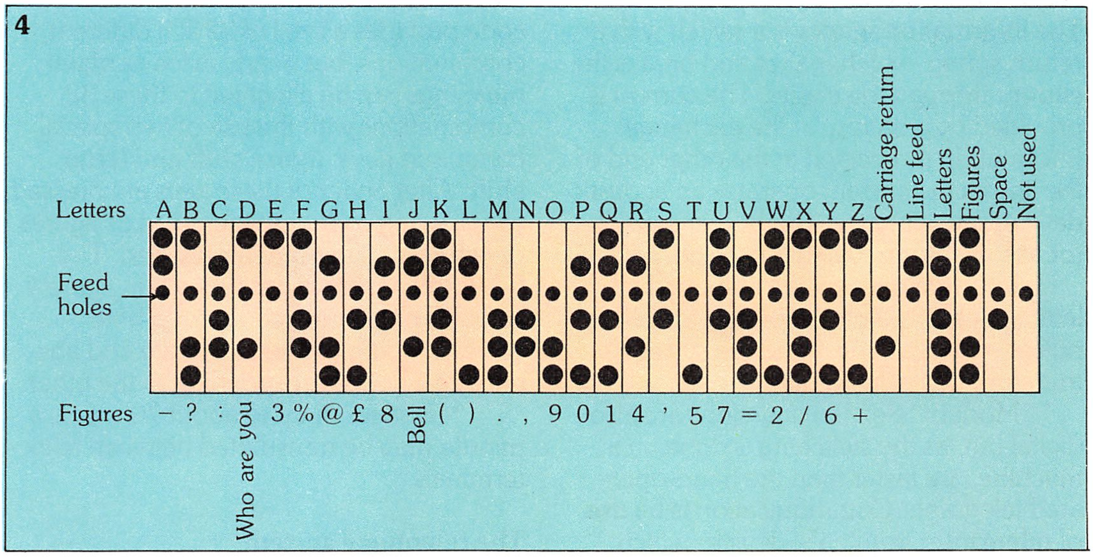
1. Block diagram representation of communication.



2. A complete telecommunications system may be broken down into subsystems.



3. **Principle behind a simple** telegraph system.



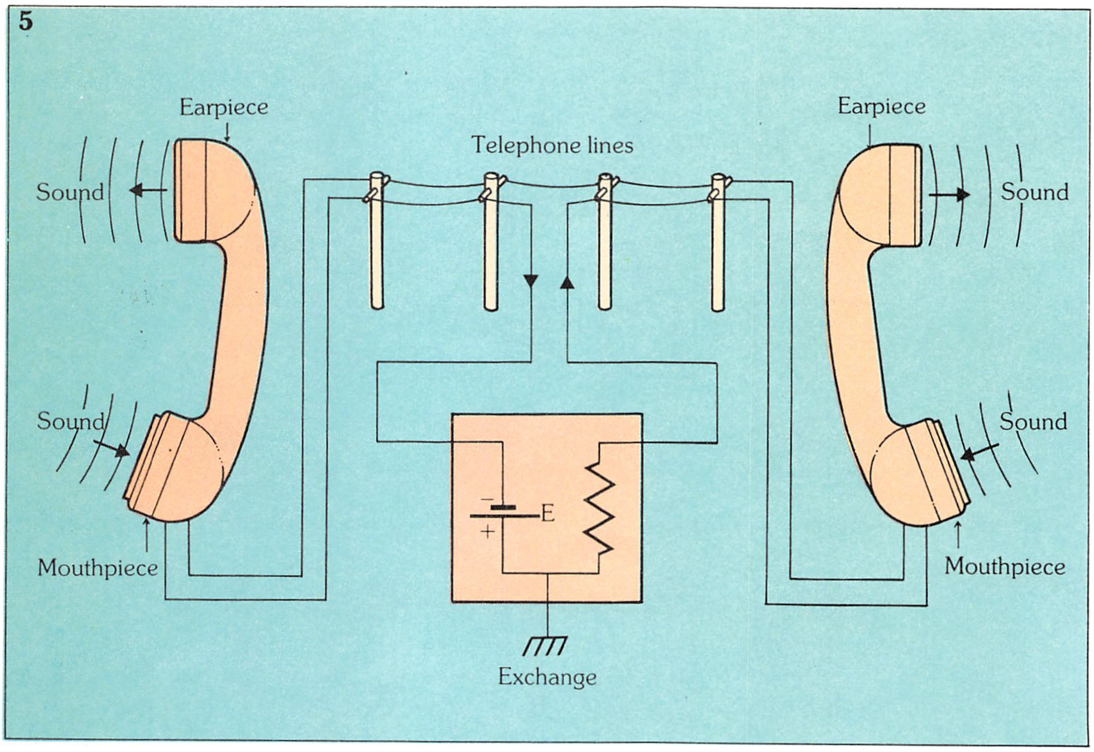
4. **Punched paper tape** showing 5-bit teleprinter code.

often be broken down into smaller parts or subsystems each following the communications principle. For instance: the radio transmitter (sender) is connected with coaxial cable (transmission medium) to the transmitting aerial (receiver); and the receiving aerial (sender) is also connected with coaxial cable (transmission medium) to the radio or television receiver (receiver).

The information transmitted in any telecommunications system must be in such a form that the sender can transmit it and the receiver can receive and understand it – there would be little point in a system, say, where a radio receiver is only able to receive radio frequency broadcasts of 250 kHz to 500 kHz, if the sender only transmits 50 kHz to 249 kHz broadcasts.

The telegraph

The principle of a simple telegraph system



5. A simple telephone system.

is shown in *figure 3*. Such a system forms the basis of modern telex-type systems. The information sender is a switch with a return spring, which makes and breaks the current through the circuit. The current is provided by a battery at the exchange. Information is received at the other end of the line as the current operates an acoustic device, say, a buzzer. The buzzer sounds for as long as the switch is pressed.

Information is coded as individual letters, in a combination of long and short pulses – Morse code – and the system is therefore digital in nature.

Modern telex transmissions are also digital but, as the switching is done by a machine, are faster than the hand-operated telegraph. Communication is by use of **teleprinter** terminals: devices which closely resemble office typewriters (i.e. they have a QWERTY-type keyboard) but also have a number **dial** and often a paper tape punch/reader. The dial is used to automatically connect one teleprinter to another, over the telex network. A printed output from both teleprinters gives a permanent record of a telex communication. Some of the newest telex terminals are similar to VDU computer terminals (see *Computers and Society 3*).

Depressing a key on the keyboard causes a 5-bit digital signal to be transmitted, corresponding to that key. The 5-bit code provides a total of $32(2^5)$ different combinations, but nearly twice as many meanings can be allocated to these 32 combinations with the use of two special command keys: **figure shift** and **letter shift**. After either of these keys are pressed, all following codes are identified as figures or letters until the other is pressed. The 5-bitpteleprinter code is shown in *figure 4* as holes on a punched tape – a hole corresponding to one logic state and absence of a hole corresponding to the other.

Messages of up to about 70 words a minute may be transmitted between telex terminals.

The telephone system

In the telephone system, communications between users take place generally over wired connections, which are given the name **bounded transmission media** (although certain connections exist using microwave and radio links). Twisted-pair, coaxial, waveguides and, in fact, optical fibres are all examples of the bounded media used in a modern telephone system. In its simplest form, a telephone system comprises two telephone handsets connected over telephone lines, together with

an exchange where a voltage source is kept (*figure* 5).

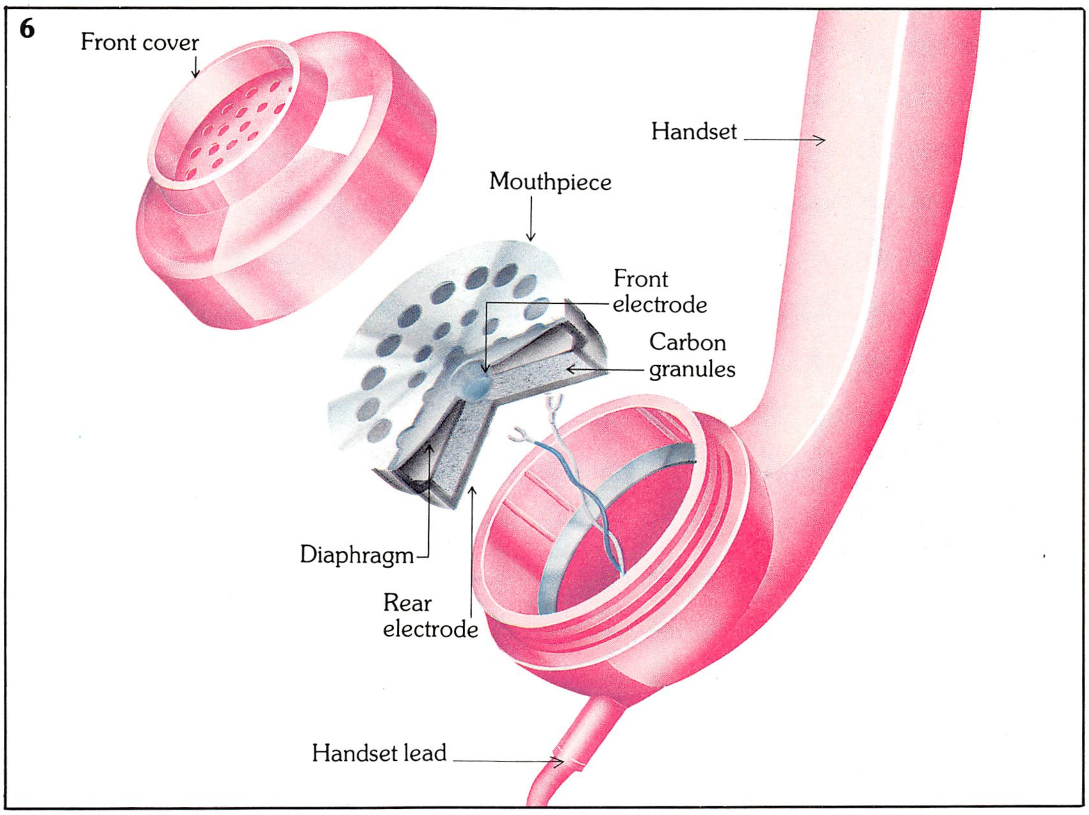
The system functions because sound waves hitting the telephone mouthpiece diaphragm (*figure* 6) cause it to vibrate in sympathy; thus, the front electrode of the mouthpiece moves in and out of the granule chamber. This chamber is full of granules of carbon which are compressed as the electrode moves into the chamber and relieved when the electrode moves back out – this lowers and raises the granule electrical resistance.

In this way, the current through the telephone network, supplied by the exchange battery, is **modulated**, i.e. varied, as the sound waves strike the mouthpiece. The mouthpiece is known as a **carbon-granule microphone** and it acts (quite successfully) as a transducer, converting sound waves to an electrical analogue signal of varying current levels.

At the other end of the telephone line, the earpiece does the opposite, coverting the varying current to sound, so that the person holding the handset can hear the information transmitted.

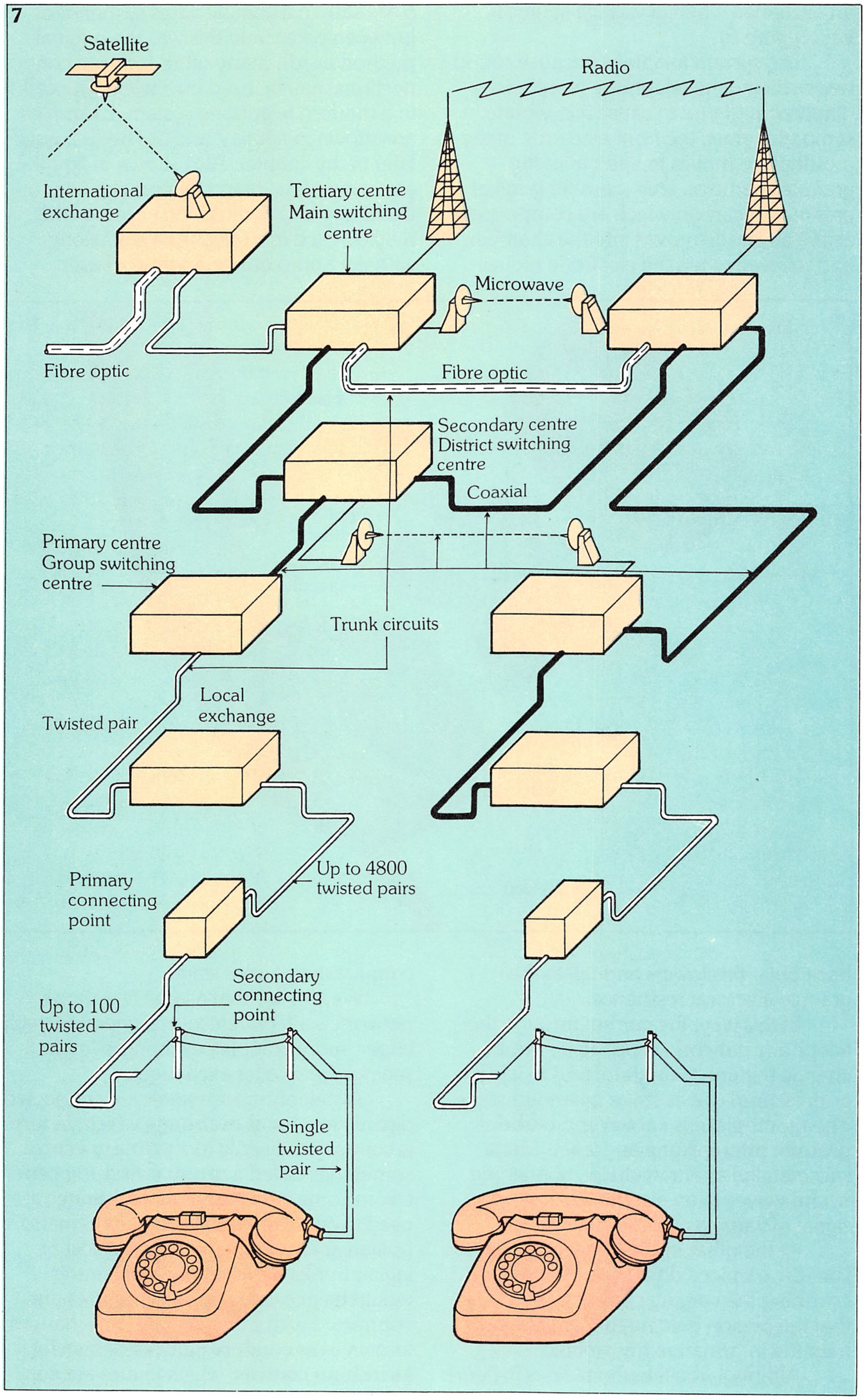
Although the telephone lines in *figure* 5 are shown as simple wires suspended between poles (and this was the original method used), many other forms of connections may be used by a telephone call in a modern telephone system. Examples are shown in *figure* 7 and will be discussed later in the chapter. Also shown in *figure* 7 are some of the many different types of exchange and **connecting points** which may be used in a telephone link, along with the approximate number of user connections at each stage.

6. The carbon granule microphone acts like a transducer – converting sound waves to an electrical analogue signal.



We can see that a large telephone network is a *hierarchical* arrangement, with larger, more complex exchanges 'overseeing' the smaller exchanges.

All telephone terminals are connected directly to a **local exchange** which, in turn, is connected directly to a **primary centre**, sometimes called a **group switching centre**. In some cases **tandem exchanges** are used to connect local exchanges in metropolitan areas where the physical cost of laying trunks between primary centres would be excessive. Primary centres are connected with trunk circuits to exchanges known as **secondary centres** or **district switching centres**, which in turn are con-



7. A hierarchical telephone network showing the various types of connections between the call sender and the receiving telephone.

nected to **tertiary centres** or **main switching centres**. Many routes exist between exchanges at each level and also between different levels in the hierarchy. In fact, a whole web of interlaced trunk circuits exists between exchanges.

Internationaal exchanges, sometimes known as **international gateways**, link a national telephone network to the international network.

Twisted-pair wires

Between the user's telephone terminal and the local exchange, connections are made with twisted pairs of wires, known as **local lines**. Up to 4800 pairs of wires may be grouped together in a cable leading from the local exchange to a primary connecting point. Similarly, cables of up to 100 pairs of wires connect each primary connecting point to a number of secondary connecting points. Users' terminals are connected either direct to the secondary connecting point, or to a distribution point which is connected to the secondary connection point by a cable of up to 15 pairs of wires.

Each pair of wires in these multiwire cables between connection points is literally formed with two insulated wires, twisted together to help reduce cross-talk.

As the distance between any telephone terminal and its local exchange is short (no more than a couple of kilometres), losses in local line circuits are quite low and so no compensation for attenuation etc. is required.

In the existing U.K. telephone network, most local lines pass only analogue speech frequency signals of about 300 Hz to 3500 Hz, corresponding to voice communications between the two users in a single call. (We shall see how this is being changed to a digitally based network in *Communications 3*.) Superimposed onto this is a DC current, required to provide power for the telephone terminal. This cannot be the case, however, between exchanges – just imagine the number of individual twisted pairs of wires which would be required to connect between all the exchanges in the telephone network so that a large number of simultaneous calls can be made in the system. (There are something like 20 million telephone terminals connected to the U.K. telephone network.) The amount of cable required would make such a network too expensive.

Instead, trunk circuits between exchanges usually carry *many* telephone signals along *single* pairs of wires. These single pairs of wires may either be twisted-pair or they may be coaxial cable. In either case, individual telephone signals are **multiplexed** (i.e. combined together) into a single signal for transmission over the trunk, in such a way that at the other end of the trunk they may be **demultiplexed** back to their original state.

The principles and techniques involved in multiplexing and demultiplexing telephone signals will be discussed in detail in *Communications 3*. All we need to know at this stage is that the greater the number of telephone signals to be multiplexed and transmitted, the greater is the bandwidth of the transmitted signal. For example, the bandwidth of a single telephone signal, in the frequency range 300 Hz to 3500 Hz, is 3.2 kHz. If we were to multiplex, say, 10 telephone signals together, the multiplexed signal will have a bandwidth of at least 32 kHz – this is, of course, a simplification of the concept but one which will suffice at this time. The point is, the multiplexed signal has a greater bandwidth than the sum of the individual telephone signals.

This greater bandwidth of a multiplexed signal can pose problems when used with transmission lines such as twisted-pair or coaxial cables because *the cables have a limited bandwidth*. Cables also introduce a significant amount of attenuation over long distance trunk circuits. Both these problems may, however, be overcome by inserting devices into the trunk circuits at regularly spaced intervals. The type of device and the interval between them depends on the type of cable used, the method of signal multiplexing, and also the number of telephone signals multiplexed.

Signals may be digitally multiplexed, for example, and transmitted along twisted-pair trunk circuits. In such a case, say, 32 multiplexed signals can be transmitted with digital **regenerators** spaced at 1.8 km intervals.

Analogue multiplexing of signals can also take place with, say, 60 signals trans-

mitted over twisted-pair trunk circuits, or 10,800 signals transmitted over coaxial cable trunk circuits. In such cases **repeaters** (i.e. combinations of amplifiers to correct for attenuation, and equalisers to correct for low bandwidth) should be placed at 20 km intervals (twisted-pair) and 1.8 km intervals (coaxial).

Other trunk circuits may, in fact, be formed by fibre optic cables, or microwave links via *line-of-sight* (i.e. short distance, point-to-point trunks) links; international links can use radio, satellite, fibre optic or cable circuits. (We shall be considering these more closely in *Communications 3*.)

Circuit switched networks

Whatever types of cables and links are used to provide the physical connections between subsets, there must be some way of setting up the call in the first place. To this end, facilities are provided in local exchanges to:

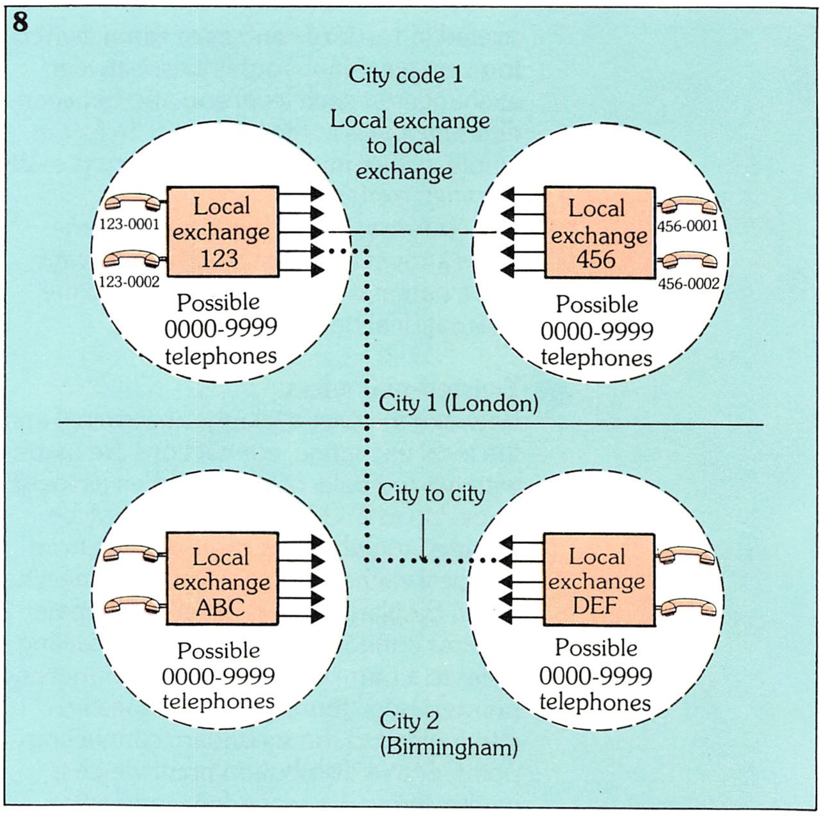
1) detect when a calling party lifts the handset from a terminal;
2) identify which other terminal is required in the call;
3) connect both terminals;
4) disconnect the link when either party hangs up, i.e. places the handset back on the terminal.

As all these facilities are built around switching circuits, and as they are fully automatic – the circuits switch themselves – they are termed **circuit switched**. The main requisites of circuit switched telephone networks are shown in *figure 8* where the telephone network of two cities is summarised. Each telephone in a city's network is assigned an individual number, and each exchange within the city has up to 10,000 telephone terminals (i.e. numbered 0000 to 9999) connected to it. Numbers may be the same from exchange to exchange, so that two terminals in different exchanges may be both numbered XXXX – only the exchange number ABC differentiates between them. So, a telephone terminal within such a city network has a number of seven digits: ABC – XXXX, and may be one of up to just under 10 million terminals.

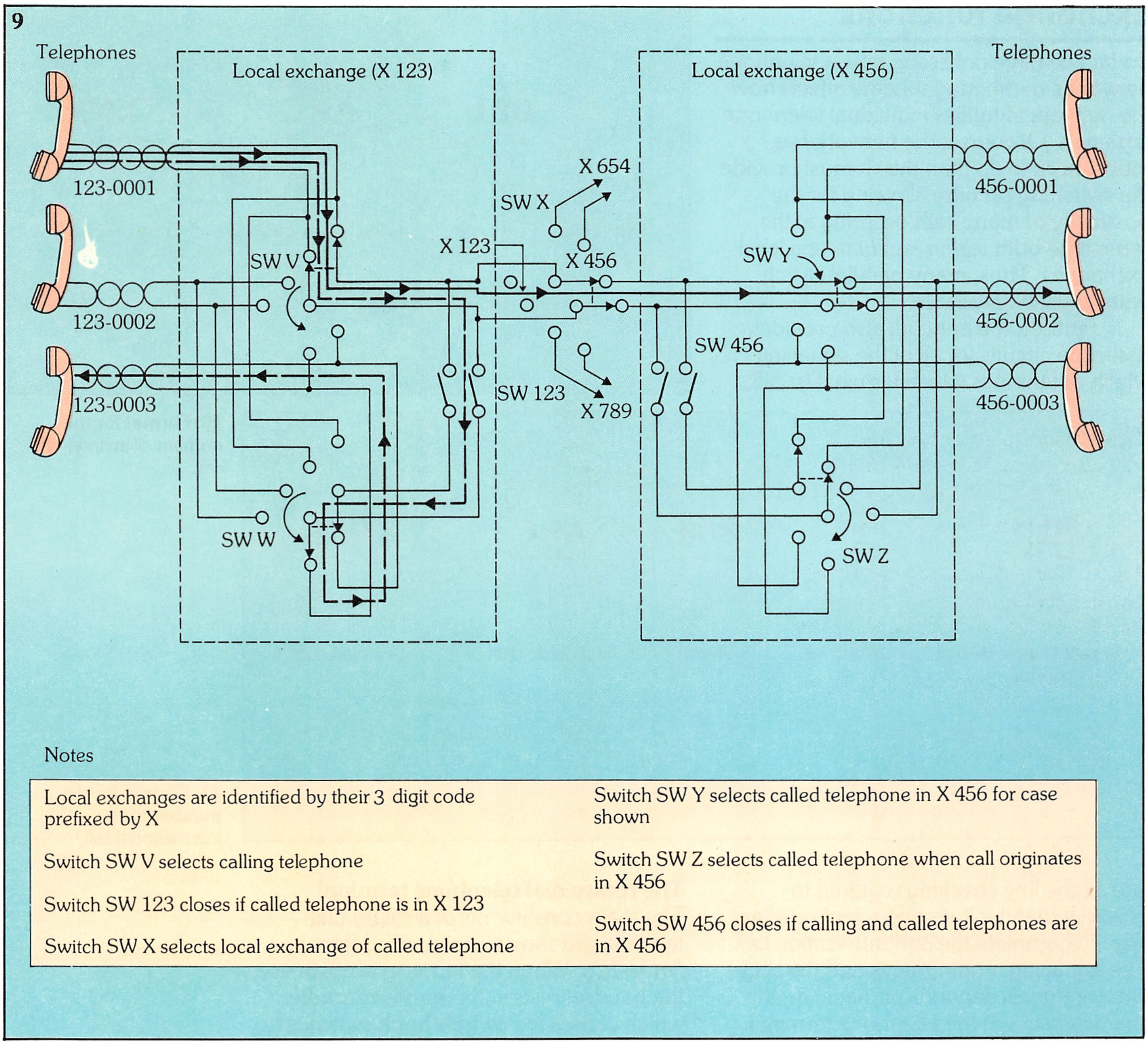
Calls from one terminal to another within the city are made by identifying the required terminal (by its seven digit number) to the local exchange. The exchange then **routes** the call through the network making the required link. *Figure 9* provides a simplified view of the physical switching needed to allow a telephone connected to one local exchange to call another telephone, connected to either the same or a different exchange.

Obviously, a telephone terminal in another city may have exactly the same seven digit number. A **city code** or **area code** must therefore be used to distinguish between cities, e.g. 1 for London and 41 for Glasgow. A caller only uses these codes if an inter-city call is required. For example, a call from a terminal inside the London network to a terminal in the Birmingham network would take the format: 21 – ABC XXXX; a call to a terminal within the same city network would take only the usual seven digit format.

There is one problem with this inter-city call arrangement, however. The city codes are ordinary digits, which will be taken by the exchange to be the first digits of an ordinary seven digit code. So, if a Birmingham terminal of format 21 – ABC XXXX was called from a London terminal, the London terminals' local exchange



8. The main requisites of a circuit switched telephone network.



9. Simplified illustration of the switching required to make a telephone call.

would route the call to the London terminal of code 21A BCXX.

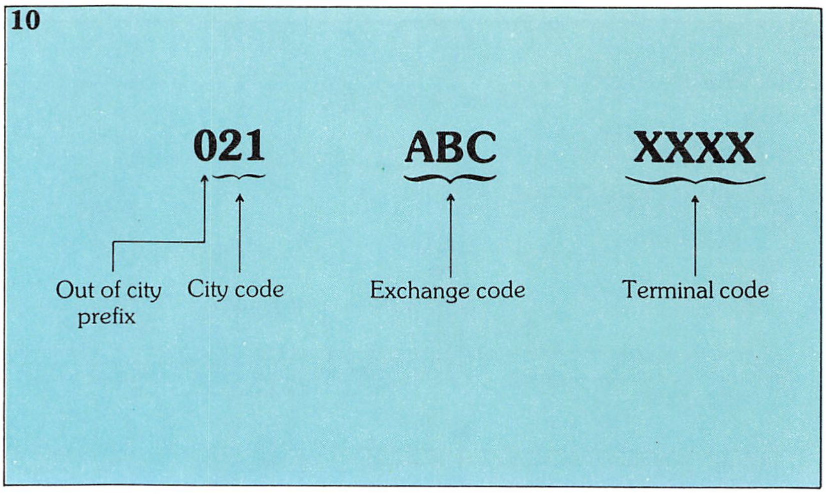
To get around this problem, a single digit, 0, is allocated to prefix the code, warning the local exchange that all following digits refer to an out-of-city call. So, the call from a London terminal to a Birmingham terminal is formatted as in *figure 10*. International calls (i.e. out-of-country) are undertaken in a similar way. The digits 010 are prefixed, which warns the local exchange that the following digits refer to an international number. The **country code** is next – this defines which country the call is to be routed to. The format of an international call is shown in *figure 11*. Finally, the city code, exchange number, and terminal number follows.

Although the length of terminal codes, exchange codes and city codes, and the prefixed numbers to obtain access for national (i.e. out-of-city) and international (i.e. out-of-country) calls, varies from country to country and in some cases within a country, the *format* is recognised world-wide. So all countries with circuit switched telephone networks, which follow this format, may connect to the international network thereby enabling automatic telephone calls world-wide.

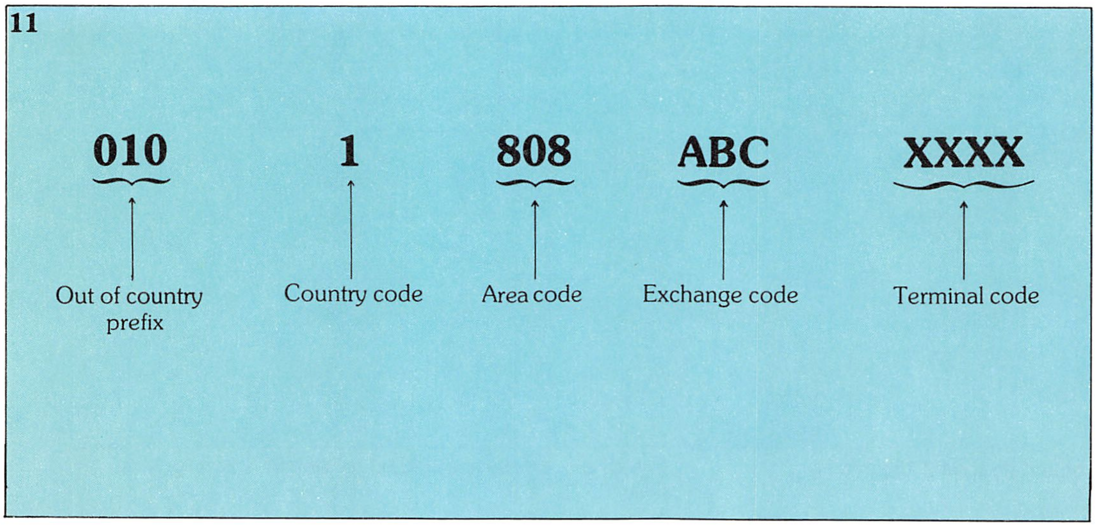
Exchange functions

So far, we have only seen how a telephone network's numbering scheme affects how the network identifies individual telephone terminals. Of course, the network has much more to do than this. It must provide the switching circuitry allowing for the possibility of many calls occuring at the same time both *within* and *between* local exchanges. Thus, many parallel switch paths must be available.

Further, the network also provides detection circuits for all of the signalling which determines which terminal to call,



10. Format for the number of an inter-city call.



11. Format for the number of an international call.

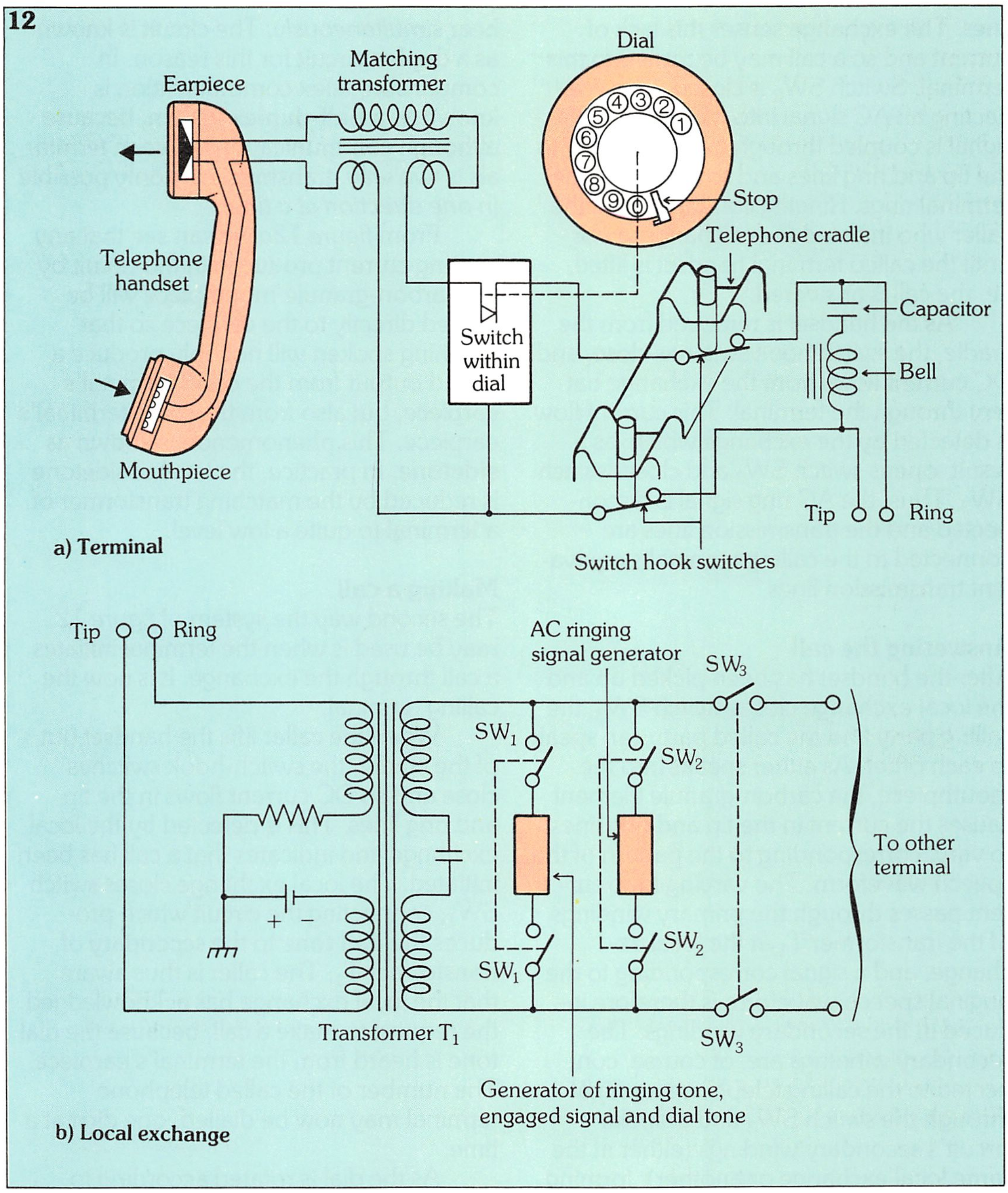
and all the line checking required to establish that the lines and telephones are clear to complete the communication link. The signalling requirements and the sequence of signals depends primarily on the characteristics of the telephone terminal. The first type of terminal we shall consider is the **common rotary dial** type.

Terminals based on this rotary dial arrangement have been in use for many years and only recently has it been common to replace them with push-button dials using digital or non-digital technology. The changeover from rotary dial to push-button dial will, however, be a gradual process because each type of terminal needs a specific type of local exchange in order to function. It will be many years before the whole U.K. telephone network contains all the necessary exchanges and equipment to maintain a *totally* digital system.

The rotary dial telephone terminal
The main constituents of a rotary dial terminal are shown in simplified form in *figure 12a*. When the terminal is not in use, the handset rests in the **handset cradle** which causes the **switch hook** switches to be open. The name switch hook derives from the early days of telephone systems when the earpiece was hung in a hook at the side of the terminal – this was connected to a switch performing the same function as the present day switch – disconnecting the major part of the terminal from the telephone network.

One part of the telephone terminal is, however, still connected to the network, the capacitor C, and the bell. The bell is a simple electromagnet, which attracts a lever when energised. The lever, in turn, strikes a metal dome as it moves, emitting a ringing sound. An AC signal sent from the local exchange to the terminal will there-

12. (a) Main constituents of a rotary dial terminal; **(b)** the local exchange.



fore ring the bell even though the terminal is effectively open circuit to DC signals.

The two telephone wires between the terminal and the local exchange are often referred to as the **tip** and **ring** connections – names which again derive from telephone systems now no longer in existence – related to plug-in connections used in the manual (i.e. operator controlled) local exchanges.

With the handset in the cradle, no DC current flows from the local exchange to the terminal. The local exchange (*figure 12b*) controls the signals to the terminal with the use of switches SW_1, SW_2 and SW_3. We can now look at the circuits which these switches connect and disconnect into the system and how the system functions as a whole. There are two main ways in which the system may be used.

1) the exchange calls the terminal;
2) the terminal initiates a call through the exchange.

We shall consider both in turn.

Calling a telephone terminal

Assuming that the handset is in the cradle, no DC current flows in the tip and ring

lines. The exchange senses this lack of current and so a call may be routed to this terminal. Switch SW_2 is closed, thus connecting an AC signal into the circuit. This signal is coupled through transformer T_1 to the tip and ring lines and so the bell in the terminal rings. Ringing continues until the caller who initiated the call hangs up, or until the called terminal handset is lifted, i.e. the call is answered.

As the handset is removed from the cradle, the switch hook switches close, and DC current flows from the exchange battery through the terminal. This current flow is detected by the exchange which, as a result, opens switch SW_2 and closes switch SW_3. Thus, the AC ring signal is disconnected and the transmission lines are connected to the calling terminal's equivalent transmission lines.

Answering the call

After the handset has been picked up and the local exchange closes switch SW_3, the calling party and the called party can speak to each other. As either speaks into the mouthpiece, the carbon-granule element causes the current in the tip and ring lines to vary, corresponding to the pattern of the speech waveform. The varying loop current passes through the primary windings of the transformer T_1 at the local exchange, and a signal corresponding to the original speech waveform is therefore induced in the secondary windings. The secondary windings are, of course, connected to the calling telephone terminal through the switch SW_3 and a similar circuit's secondary windings (either at the same local exchange or another), forming a speech link from the called terminal to the calling terminal.

As the calling terminal is connected to a similar circuit at its local exchange, so speech waveforms at *its* mouthpiece pass as a varying current to the secondary windings of the called terminal's transformer T_1. The varying current therefore induces a current in the primary windings which passes along the tip and ring lines to the called terminal's earpiece, where a corresponding sound wave is produced.

Communication between the two telephone terminals is thus two way – both called and calling parties may speak and hear *simultaneously*. The circuit is known as a **duplex** circuit for this reason. In comparison, telex communication is known as a **half-duplex** system, because although communication between terminals is two way, transmission is only possible *in one direction at a time*.

From *figure 12a* we can see that any varying current produced in the circuit by the carbon-granule mouthpiece will be passed directly to the earpiece so that anything spoken will not only produce a sound output from the other terminal's earpiece, but also from the *same* terminal's earpiece. This phenomenon is known as **sidetone**. In practice, the level of sidetone is reduced by the matching transformer of a terminal to quite a low level.

Making a call

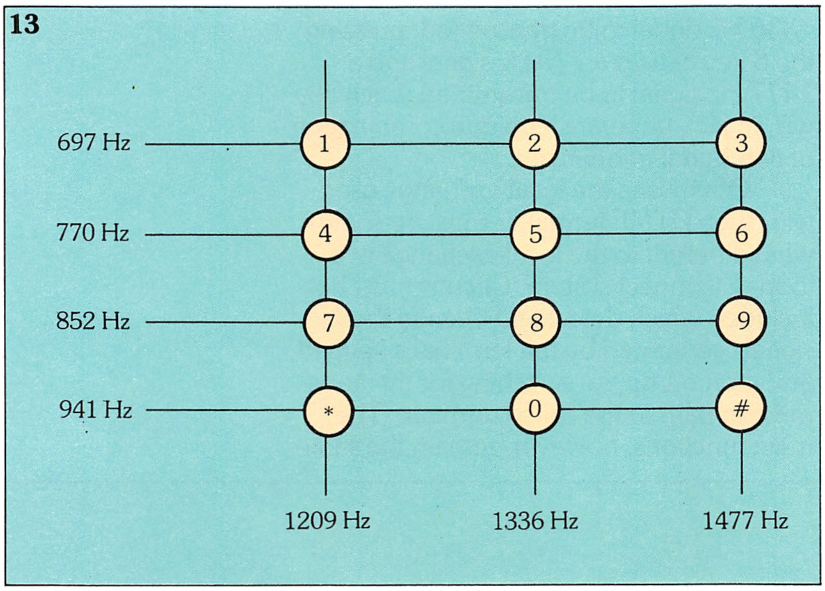
The second way the system of *figure 12* may be used is when the terminal initiates a call through the exchange. It is now the calling terminal.

When the caller lifts the handset out of the cradle, the switch-hook switches close and so DC current flows in the tip and ring lines. This is detected by the local exchange and indicates that a call has been initiated. The local exchange closes switch SW_1, connecting the circuit which produces the **dial tone** to the secondary of transformer T_1. The caller is thus aware that the local exchange has acknowledged the request to make a call, because the dial tone is heard from the terminal's earpiece. The number of the called telephone terminal may now be dialled, one digit at a time.

As the dial is rotated according to each digit required, and allowed to rotate back to its rest position, the DC current in the tip and ring lines is interrupted by the switch contacts in the dial. The number of interruptions is, in fact, equal to the number dialled.

As the dial is rotating, extra switches (not shown) disconnect the earpiece so that the clicks which the interruptions cause cannot be heard. The dial is mechanically designed to provide about 10 interruptions or pulses in a second, as it rotates back to rest.

The pulses are received by the local exchange which detects the sequence of



13. Frequencies generated by a DTMF keypad.

numbers dialled, and stores them. The numbers are used by the local exchange to locate the called terminal and set up an available transmission path.

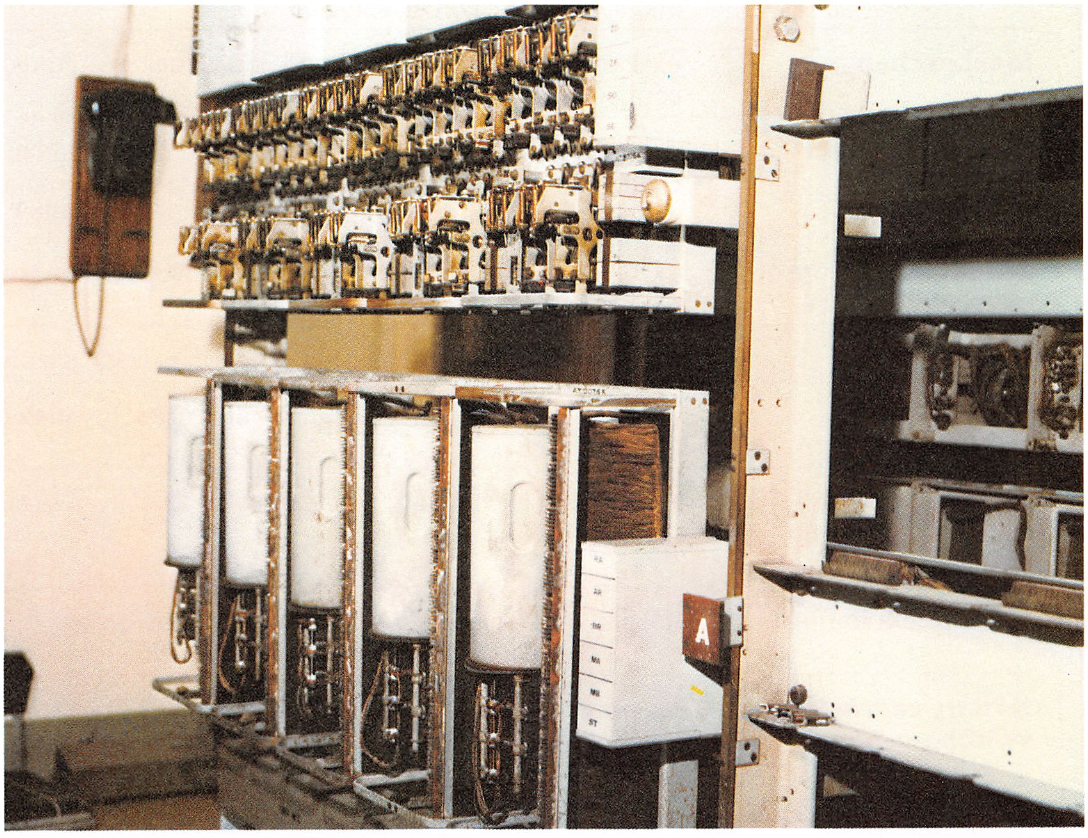
When the called terminal is located, *its* local exchange sends a ringing signal to it if the handset is in the cradle. At the same time a **ringing tone** is transmitted to the calling telephone terminal, from its local exchange, so that the calling party is aware that the called terminal is ringing. The ringing tone continues until either the called party answers, or the calling party replaces the handset in the cradle. If the called party answers the call, the procedure is the same as we saw before – only at the local exchange of the called terminal – and the transmission path between the two terminals is completed.

Engaged terminal

If the called terminal is **engaged**, i.e. the handset is not in the cradle, the tone generator will send an **engaged signal** or **busy tone** back to the calling terminal so that the calling party is made aware of it.

This type of digit signalling, using a mechanical dial to create disconnection pulses in the tip and ring lines between terminal and exchange is known as **loop-disconnect signalling**. Loop-disconnect pulses may also be generated by a push-button type of numerical keypad. In a terminal with this type of keypad, internal circuitry is used to create a number of pulses corresponding to the number of each button pressed. Such a telephone

Right: Strowger switching equipment at the Kings Cross Exchange Director.



The Research House/British Telecom

terminal may be used with the local exchange we have seen here.

Another method of digit signalling is known as **dual tone multifrequency** (DTMF) signalling sometimes called **touch-tone**, and also uses a push-button numerical keypad. Instead of generating loop-disconnect pulses however, the internal circuit transmits a combination of two signals over the local line between terminal and local exchange. The actual frequencies generated by a typical DTMF keypad are shown in *figure 13*. For example, pressing the 5 key causes a 770 Hz signal and a 1336 Hz signal to be transmitted; pressing the 6 key causes a 770 Hz signal and a 1477 Hz signal to be transmitted. Each key will, in fact, generate a unique combination of two signal frequencies.

Obviously, the local exchange used with such DTMF terminals must be somewhat different to the local exchange of a loop-disconnect system. Circuits must be included which detect and decode the signals generated by the terminal's keypad, and then set up the switching for the transmission path to the called terminal. The main functions, however, remain the same.

Glossary

circuit switched network	a network in which automatic switch circuits define the route which a call takes between terminals
dual tone multifrequency (DTMF)	digit signalling method used in which two signals are transmitted corresponding to a digit. The two frequencies are unique to the digit
duplex	communications system which allows simultaneous two-way communications between parties
half-duplex	communications system which allows two-way communications, but in only one direction at a time
local exchange	exchange at the first level. All individual telephone terminals are connected to a local exchange
loop-disconnect signalling	digit signalling method, normally using a rotary dial, in which the DC current between local exchange and telephone terminal is interrupted a number of times corresponding to the number dialled
primary centre, group switching centre	exchange in a national network at the next higher level than a local exchange
regenerators	circuits which regenerate digital signals in a digital telephone trunk
repeater	amplifier/equaliser circuits which are used in analogue telephone trunks
secondary centre, district switching centre	a telephone exchange at the next higher level from a primary centre
tandem exchange	telephone exchanges in metropolitan areas, where the cost of laying trunks between primary centres would be excessive
tertiary centre, main switching centre	telephone exchange at the next higher level from a secondary centre

3

COMPUTERS & SOCIETY

Office automation

What type of work can computers handle?

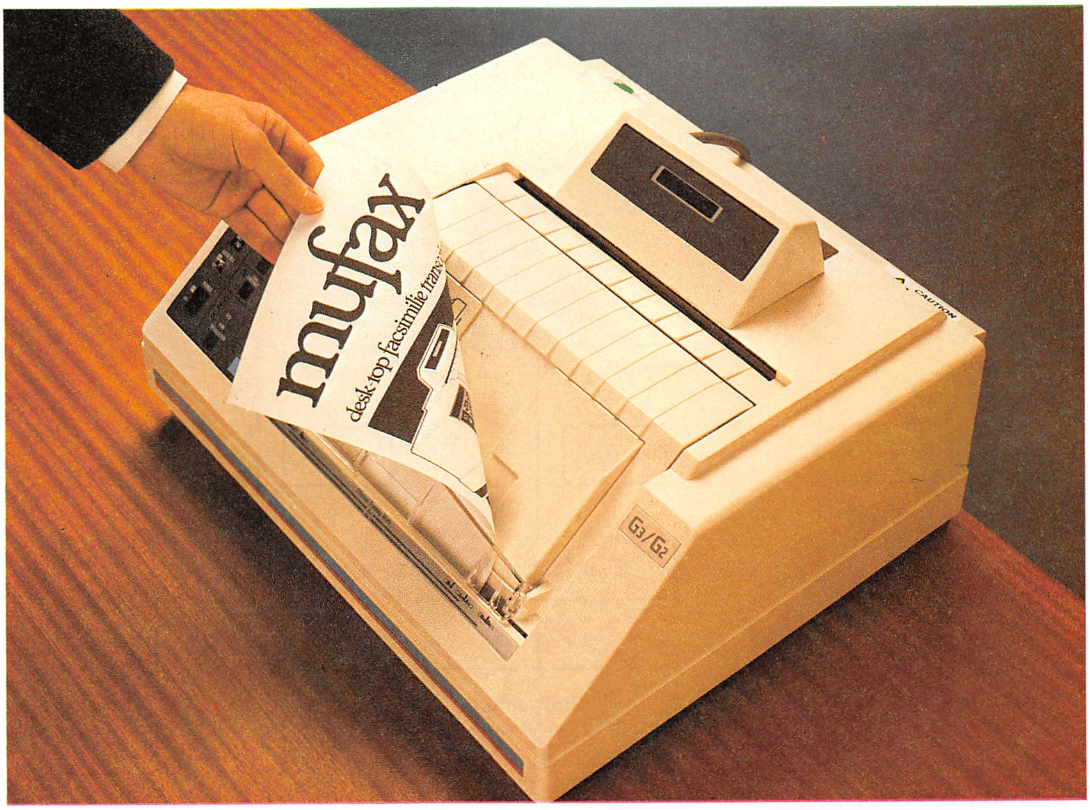
There are two quite different types of 'work': structured and unstructured. The former has been the easiest to automate so far and includes the routine clerical jobs that were mentioned in *Computers and Society 2:* filing names and addresses, addressing envelopes and so on. A computing system designed for this kind of work is known as an **operational system**.

The second type of work that is performed in an office environment is decision making – the kind of computer system needed to aid this unstructured work is more an **information system**.

All managers need support for their decision making; pertinent information is necessary to supplement experience and intuition. Usually, the higher up the management ladder as person is, the further away the person is from the base of company information that is needed.

Computers provide information to managers in the form of printed reports, or even as on-line data, flashing up on demand on their VDUs. One interesting effect of this instant information is that some managers have now begun to participate more actively in the management of operations. For the first time, in some cases, they have up to the minute data to which they can immediately respond.

It is these effects that will be the next stage in the development of the 'office of the future' – but let us first look at what present day automated offices are capable of achieving.



Right: Muirhead Model 7800 facsimile machine. (Photo: Muirhead).

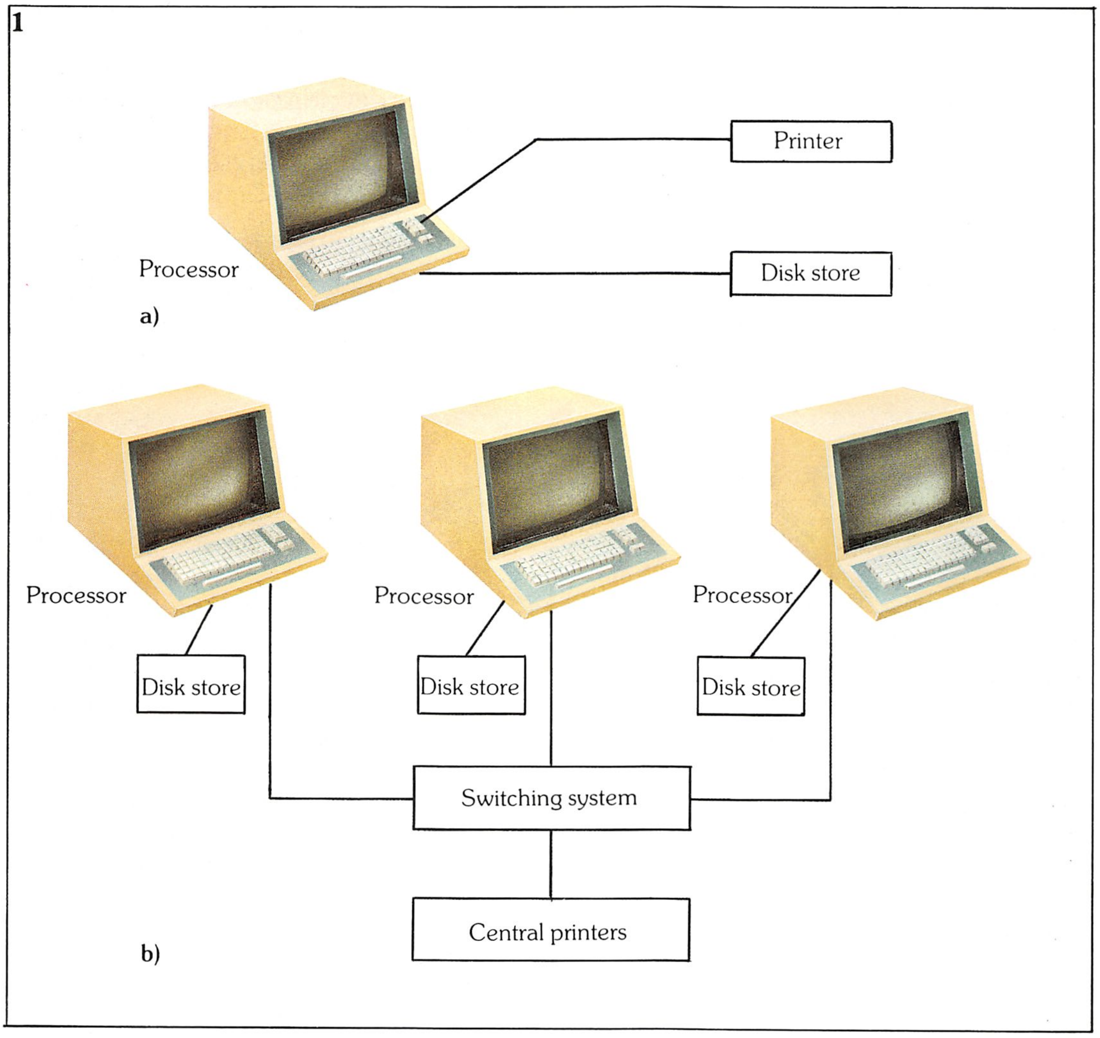
Document management

Word processing (or WP) is probably the first thing that comes to mind when talking about computers in the office. Because this new concept of an office uses technologies which are new, some of the ideas and much of the jargon is also new. However, one point to remember is that office work hasn't changed, only the tools have changed.

In its simplest form, word processing is a way of creating, revising, printing and storing text. The software for such a system has been specifically designed and written to efficiently manipulate words. In most systems, this software is stored on disks and transferred to RAM before it is used; in some cases, a special program may be stored permanently in ROM – these 'soft' programs built into the hardware are known as 'firmware'.

The software that performs WP or accounting, for example, is an applications program. The simplest type of WP program is known as a **context editor** and was originally designed as an aid in the entering and editing of programs on a computer. Such editors are line oriented, which means that they can only handle one line of text at a time. These editors are used largely for creating simple, short documents and are therefore useful for portable computers or executive workstations.

The true predecessor of the word processor, though, is the **screen editor** – this allows movement of the cursor around a screenload of text. Screen editors were followed by **document formatters**; special codes are embedded in the text which, when run through the formatter program, are interpreted and the text document is formatted accordingly. The increasing intelligence of terminals then enabled the



1. (a) A stand-alone word processor which runs a dedicated WP system; **(b)** distributed processing system which may run many different packages, including word processing.

effect of these format codes to be displayed on the screen in *real time* – it is this feature which distinguishes a word processor from its editor/formatter predecessors.

User friendly systems

There are two ways of approaching word processing in the office: dedicated word processing and WP packages. The dedicated system can, as its name suggests, only perform text manipulation functions – the hardware and software cannot do anything else (*figure 1a*). A WP package, on the other hand, can perform all the functions of a dedicated WP system but is able to run on a distributed processing system alongside other packages which might, for example, also handle accounting (*figure 1b*).

For the keyboard operator, dedicated systems are probably easier to use as they have more 'user-friendly' facilities built into them. For example, the instructions on the various keys might include: 'copy'; 'merge'; 'delete'; move; which are self-explanatory. As a WP package runs on a larger computer system, the keyboard operated by the user does not have these same 'friendly' keys.

A user friendly program or system offers considerable help to the operator, usually in the form of messages or prompts on the screen. Some word processors also use a 'beep' to inform the user if an 'illegal' command has been sent.

Help messages are also used – these explain each program feature. When in difficulty, pressing the 'help' button, or keying in a one or two letter command, will summon a **menu**, or list of options, to enable the user to sort out the problem. Some of the better word processors also feature teaching options or tutorials with cassettes.

Using a word processor

Depending on the system, the screen may either be blank, or there may be a line of information at the top or bottom of the screen. This is known as the **status line** and includes information regarding: the name of the file that is being worked on; the length of the file in characters; and where in the file the cursor is – by page number and by line and column number. The screen may also have a ruler line, which shows where the margins and any tabulation stops, or tabs are set. In addition, there may be a help menu describing the most frequently used commands.

The cursor, which may be a block or square, a triangle or a line, indicates the position on the screen that the operator is in. It may flash on and off so that it's easy to see and it can be moved up or down, a line at a time, or left or right, a character at a time. The ability to move the cursor to any place on the screen, means that any word or phrase can be modified instantly, without the need to retype an entire page. This is the single most important advantage of using a word processor, rather than a typewriter.

Features such as: **word wrap** (the automatic wrapping around of text at the right-hand margin without the need for a carriage return); the ability to **move blocks of text** around in the file; and the ability to **insert** new text and **delete** unwanted text, considerably improve productivity at the workstation. Because of this, these features are of benefit both to employers and to employees, as the boring repetitive retyping of documents is no longer necessary.

Another useful feature is the **search and replace** function. This enables the user to automatically correct an error each time it occurs. Some of the more advanced word processing systems also possess **hyphenation** dictionaries and spelling and grammar checking programs.

In addition to these editing commands, there are many other commands that define how the text is to be printed. At the touch of one or two keys, a word may be underlined or emboldened; a paragraph may be single or double spaced; margins can be reset thus reformatting the text to fit different sizes of paper; and the text can be justified (i.e. aligned on the right-hand side as it is on the left).

As the VDU is only able to display about 24 lines of text at a time, the computer moves the text upwards a line at a time in a scrolling motion, as text is being typed in – this is **vertical scrolling**. The text format may also be wider than the number of characters that can be seen on one screenload, **horizontal scrolling** moves the text from right to left. In this way

Table 1
Word processing feature checklist

Cursor movement
move cursor left and right by character/word
move cursor to left and right of a line
move cursor up and down one line
move cursor to top of screen (1st character of 1st line)
move cursor to bottom of screen
move cursor to beginning/ end of document
move cursor to next screen
move cursor to start of next line
move cursor to a specified page

Scrolling
scroll text up and down one line
scroll text up and down one screen
horizontal scrolling

Screen formatting
set/clear tabs
set left and right margins
margin release
automatic page breaks
'what you see is what you get'

Insertion and deletion
Insert character
delete character/next character
delete preceding character
delete next word
delete remainder of line
delete preceding part of line
delete entire line
delete to end of document
delete through specified character
delete paragraph

Block operations
copy block (of text)
move block
delete block
erase all block markers

Search and replace operations
find string
find string and replace
find string and replace *n* times
global find and replace
repeat last find operation
ignore a specific string occurence when searching
match only whole words
search and replace operations using 'wild cards'
search and delete

Page layout
set top, bottom, left, right margins
insert page headings
insert page footings
set heading margin
set footing margin
set physical page length
set number of characters per inch
set number of lines per inch
temporary left margin offset
indent first lines of paragraphs
outdent first lines of paragraphs
number paragraphs
insert <LF> between paragraphs
suppress headings and footings
page numbering
page number suppression
force new page
two-column printing

Justification
right justify
center
hard (unsplittable) spaces
automatic alignment of decimal data

Character attributes
underline
boldface
italics
colour
shadowed (double strike)
proportional spacing
superscript
subscript
overprint

Printer control
print a specified page
print starting from a specified page
print through a specified page
print starting from cursor position
print multiple copies
display/change print format
pause for paper insertion
typesetter

Document/file operations
link/merge WP documents and non-WP documents (i.e. VisiCalc)
move text blocks from document to document
copy text blocks from document to document

Miscellaneous
columnar math
automatic table of contents
automatic index

the VDU acts as a *window* scanning the text file.

There is usually a volume control on the VDU so that the noise made when typing can be adjusted. This is very important as the noise provides feedback to the operator that the keys have been pressed correctly.

A checklist of word processing features is shown in *table 1*.

Office communications

The term electronic mail is used in two ways: generally, it refers to all forms of communication involving electronics, including telex and facsimile; secondly, and more specifically, it involves communication between computer workstations and distributed networks. Even in this simple form, the term is not quite specific enough, does it include viewdata for instance? This section of the article therefore covers telex, teletex, facsimile and viewdata, as well as computer-to-computer mail and electronic mailbox systems.

Communications will be the major focus of office development over the next ten years. Surveys have shown that the majority of messages are still initiated in long hand and then either dictated to secretaries or typed from long hand notes. This is usually followed by amendments and retyping, perhaps, and searching for addresses, typing of envelopes and so on.

The sophisticated electronic mailbox tackles all these areas. Viewdata can be seen as a less flexible form, and that is why it is included in our discussion. Telex and facsimile address only the transmission problem, rather than the organisational problems of message generation and storage. For these reasons, our look at telex and facsimile will be fairly brief.

Telex

A few years ago, the telex system in the United Kingdom was saturated and there was an eighteen month waiting list in central London. The equipment itself was old fashioned and was slowly being superseded by facsimile transmission.

Liberalisation in late 1982 and early 1983 changed this. The London waiting list was reduced to about three months and more advanced machines became available. ITT was the exclusive supplier to the Post Office, but a number of other companies began manufacturing advanced terminals for direct sale to the public.

The most advanced telex machines look like word processors with keyboard, printer and VDU. The message is composed on-screen, and may be edited using typical WP commands. In addition, messages may be prepared and edited while, at the same time, the machine dials the number (and also automatically redials frequently if the number is engaged), checks the answerback and sends the message. This process is known as **store and forward** – a large network of such devices is often managed by a central computer, a **message-switch**.

If these machines were equipped with local mass storage (e.g. disks), then they would be as sophisticated as WPs, with the advantage that they could communicate with other machines on the telex network. However, they are restricted to a transmission speed of 50 bit s^{-1} or roughly six characters per second. A 250 word page of A4 text would thus take about four minutes to transmit.

Word processors over leased lines can transmit and receive data at 9,600 bit s^{-1} and in local area networks they work at up to 10 Mbit s^{-1} (1 Mbit s^{-1} in practice). This slow transmission speed is not really a

Table 2
Electronic mail: installed base in the U.K. as at December 1983

Type of service	1979	1980	1981	1982	1983	1984	(1985)
Facsimile	10,000	12,150	14,800	18,000	23,600	30,000	(37,000)
Telex	99,000	102,000	107,000	112,500	121,000	126,000	(130,000)
Viewdata	5,500	8,000	16,000	30,000	55,000	90,000	(150,000)
Computer-to-Computer	2,500	3,500	5,000	10,000	20,000	35,000	(42,000)
Electronic Mailbox	—	—	—	6	15	30	(55)
Total installed base for all electronic mail terminals (including intelligent copiers)	102.6	111.2	127.9	155.2	203.8	235.3	(356.6)

Source: Euromonitor report – Advanced office equipment in the eighties.

matter of equipment. Speeds are restricted because telex lines are multiplexed with up to 24 messages travelling on any one line. The U.S. and Canada, in comparison, use 110 bit s^{-1} telex, and France and Germany use 200 bit s^{-1} telex.

The advantage of telex is the massive installed base of its users (see *table 2*). There are well over 100,000 telex lines in the U.K., excluding private networks; a further 20,000 terminals form part of private networks. The investment in telex appears to be too great for it to be dropped.

The Research House/British Telecom

Above: Cheetah telex equipment.

Teletex

Teletex is an international standard for electronic communication and was first introduced by West Germany in 1981-1982. Its advantage is that it operates at 2,400 bit s^{-1}, about 30 times faster than telex. Existing word processors can easily be converted to teletex transmitters, it's only a case of the terminal using the correct protocol and following the standard.

Facsimile

Facsimile, or fax, is a system that delivers copies of documents to remote locations. The original document is scanned and its image is converted to an electrical signal. It is a very fast method of transmitting visual, non-codeable information, like weather maps and photographs, for example. The fax machine is very popular in Japan because of the huge size and pictorial nature of the Japanese alphabets.

Fax has an advantage over communicating word processors in that there are international standards for fax transmission. The CCITT has specified details for three different performance groups of fax machines: groups 1 and 2 are for **analogue fax** (the electrical signal varies with the intensity of the image, from black to white through grey); and group 3 for **digital fax** (the electrical signals represent discrete picture elements of the image as either black or white without grey tones).

The only drawback of digital fax is that it does not permit the nine levels of grey scale possible with analogue techniques.

The facilities now being built into fax machines include the following: paper size selection by transmitter; resolution/speed selection; automatic dialling/answer; fail-safe transmission (error checking); and encryption facilities.

Facsimile provides the facilities for reasonable quality copies with little operator attendance. However, these facilities are expensive and manufacturers have therefore split the fax market into three areas: operational, convenience and specialised.

Operational fax applies to those users for whom over half the traffic is of special purpose documents, for example, daily business reports. In this category, greater sophistication is required, particularly facilities such as unattended reception, automatic dialling and automatic loading. Depending on the application, the quality of the image and paper is not always important. **Convenience fax** users have unscheduled traffic, and again the quality of transmission is fairly unimportant.

The **specialised fax** user, on the other hand, wants the quality and sophistication of service which is normally outside of general office use. Included here are such things as military applications and transmission of cloud pictures, newspapers and fingerprints.

Facsimile currently exists as one of a number of separate elements of an office system. However, the developments that are bringing together the other elements of office systems are also now embracing fax, therefore making it an integrated part of the automated office.

(continued in part 29)